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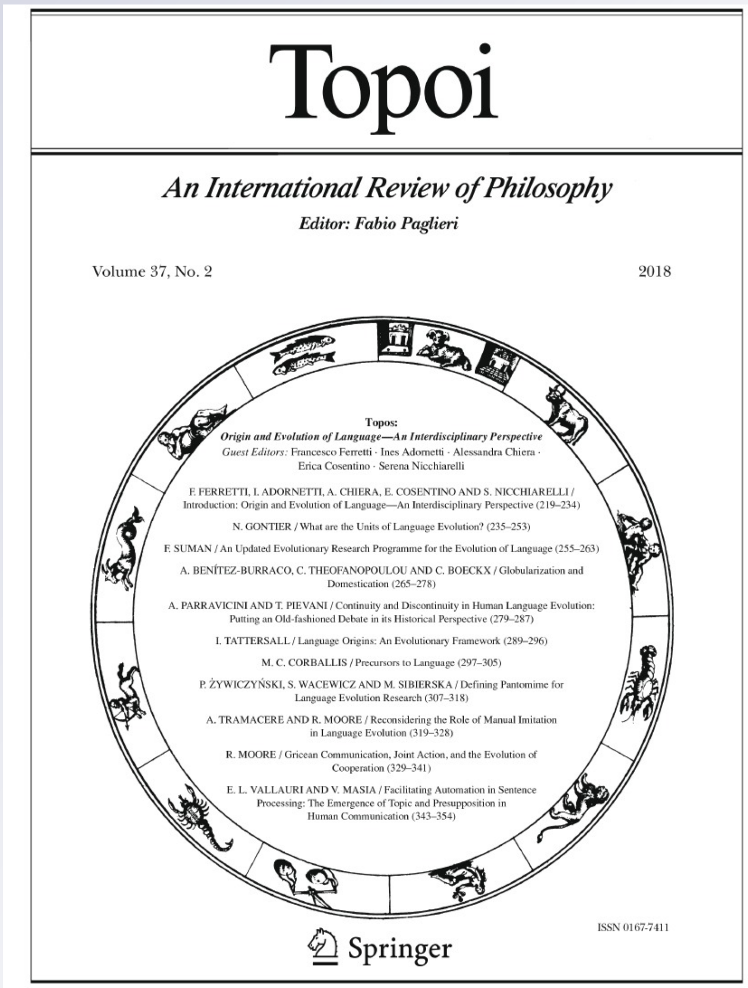
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What are the Units of Language Evolution?

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Abstract Universal Darwinism provides a methodology to study the evolution of anatomical form and sociocultural behavior that centers on defining the *units* and *levels* of *selection*, and it identifies the *conditions* whereby natural selection operates. In previous work, I have examined how this selection-focused evolutionary epistemology may be *universalized* to include theories that associate with an extended synthesis. Applied evolutionary epistemology is a metatheoretical framework that understands *any and all kinds of evolution* as phenomena where *units evolve by mechanisms at levels of an ontological hierarchy*; and it provides *three heuristics* to search for these units, levels and mechanisms. The heuristics are applicable to language and sociocultural evolution, and here, we give an in-depth analysis of how the unit-heuristic can be implemented into language origin and evolution studies. The importance of developing hierarchy theories is also more fully explained.

Keywords Applied evolutionary epistemology · Evolutionary linguistics · Units · Levels · Evolutionary mechanisms · Hierarchy theory

Abbreviations

LE	Language evolution
EE	Evolutionary epistemology
AEE	Applied evolutionary epistemology
SVT	Supra-laryngeal vocal tract
I-language	Internal language
E-language	External language

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1 Introduction and Outline

Language origin and evolution studies face two major problems (Part 2). Scholars study numerous language-associated phenomena because they disagree on what language is and how it evolved (Sect. 2.1); and at present, no criteria exist to choose amongst opposing theories (Sect. 2.2). Consequently, obtained data and results remain juxtaposed, and a unified theory on language and its evolution remains absent.

Here, we circumvent the definitional problem and show how applied evolutionary epistemology (AEE) provides a uniform methodology for evolutionary linguists (part 3). AEE (Gontier 2010a, b, 2012) is a methodology derived from how Universal Darwinists study how evolution occurs by means of natural selection, but it also incorporates theories associated with an *extended synthesis*. AEE defines evolution as the phenomena where *units evolve at levels of an ontological hierarchy by mechanisms*.

Implementing AEE into evolutionary linguistics, therefore, involves a systematic search for the *units, levels,* and *evolutionary mechanisms* involved in LE (part 4). I introduce *three heuristics* whereby we can identify, examine and evaluate all three and I give an in-depth analysis of the unit-heuristic (part 5). I end by pointing out future prospects for research (part 6). For an in-depth analysis of the level- and mechanism-heuristic, I refer the reader to Gontier (2017).

2 Two Problems for Evolutionary Linguistics

We first analyze the definitional problem and then examine the methodological problem that confronts evolutionary linguists.

2.1 The Definitional Problem

Evolutionary linguistics today combines data from linguistics, anthropology, primatology, archaeology, neurology, and psychology. Scholars disagree on what language is and this impacts how they study its evolution. Some understand language as a unique human capacity, others say it evolved from animal communication systems, and still others assume the existence of an intermediate protolinguistic stage.

Bio-linguists define language as an *individual and inborn neurocognitive capacity* (Lenneberg 1964). Chomsky (1999) and co-workers (Berwick and Chomsky 2016) divide this *faculty of language* into three components; the *sensorimotor system* that enables language output (speech or gesturing), the *conceptual-intentional system* that provides the input for language (thought that underlies the lexicon), and the *cognitive capacity to merge* that enables recursion (that characterizes universal grammar). Merge is defined as the basic property of human language, and recursion defines the faculty of language in the narrow sense (FLN). The other two systems are part of the faculty of language in the broad sense (FLB), and components of it are shared with other animals (Hauser et al. 2002). The distinction between the FLN and FLB is a reinterpretation of what Chomsky originally called I-(nternal) and E-(xternal) language. Both the FLB and FLN are recognized to be part of an "organism-internal environment" that they oppose to an "external environment" that is divided into "social", "cultural", "physical", and "ecological" layers or realms. With this distinction, they take the *hierarchical* nature of reality into account.

In humans, the FLB is said to enable a "secondary system of *communication*" (Berwick and Chomsky 2016: 64), but for Chomsky, language primarily facilitates internal thought. *E-language* is traditionally studied by diachronic linguists, anthropologists and psychologists. These have shown that, although words might be inventions of an individual's conceptual-intentional system, for these to become learned by others and integrated into a society's lexicon, *sociocultural interaction and transmission* is required. E-language-related phenomena including *language acquisition, variation, change, and diffusion* therefore often require *group-level* explanations that go beyond I-Language.

(Animal) communication systems are also defined differentially. Weaver and Shannon's (1963) model defines communication as the *transfer* of a *signal/ message/ information* between a *sender* and a *receiver*. A *signal/ message/ information* may refer broadly to *emotions, facial expressions, vocal calls and gestures* of both human and other animals (Darwin 1872), or it may refer specifically to *co-verbal gesturing* (Goldin-Meadow 2007) or *body language* that accompanies modern language. And although animal communication systems can be understood narrowly as *signals* (Maynard Smith 1974; Krebs and Davies 1978), they can also encompass *behavioral repertoires* that include *maternal bonding* (Altmann 1974) or *grooming* (Dunbar 1998). Animal communication systems are often *species-specific*, but they also convey meaning *interspecifically* (in predator–prey relations, for example); and Witzany (2014) has recently drawn attention to *intra-organismal communication* that occurs between different bodily organs or between a host and its microbiome.

Finally, beyond language and communication, a rising number of scholars today investigate *protolanguage*. Originally, the term referred to a hypothetical *stem* obtained from comparing manuscripts, or it denoted a hypothetical *urlanguage* acquired from using internal reconstruction methods (Schleicher 1861–1862). Today, it also refers to a hypothesized but considered real communicative/linguistic system used by early modern humans and perhaps other hominins (Bickerton 1990; Tallerman 2011; Wray 1998).

Scholars thus continue to disagree on the nature of (animal) communication, proto-language, and language and proposed definitions are often intensional/functional, exclusive, outdated, and incongruent with actual scientific practices. Definitions are *intensional/functional* because they seek to find the essential or functional characteristics of language. They are *exclusive* because they single out one phenomenon to the exclusion of all others (e.g. the biological capacity versus the sociocultural transmission of language versus language as a system). They are *outdated* because some definitions are over 100 years old (e.g. de Saussure's (1916) *language, langue, and parole*), and they were often formulated within a *non-evolutionary context* (e.g. Shannon–Weaver's model). Instead, definitions remain based upon classic dichotomies including the innate-acquired or biological–cultural, animal–human or continuity–discontinuity, or historical diffusion–biological evolution divides. Finally, definitions are *incongruent with actual scientific practices* because scholars do not study communication, protolanguage or language as monolithic wholes and from within a specific biological, neurological, cultural or linguistic domain. Instead, they realize that the entities referred to are heterogeneous. That is why they focus on a wide variety of genetic and anatomical features, neuro-cognitive capacities, individual and group behavioral patterns, or the properties of linguistic systems.

Examples of the latter include specific *genes* such as the *FOXP2* or *MICROCEPHALIN* gene (Jackson et al. 2002; Lai et al. 2000, 2001; Vargha-Khadem et al. 2005); the *anatomy* of orofacial muscles (Gaspar et al. 2014), hand bones (Marzke 1999), and the supra-laryngeal vocal tract (Fitch 2000; Lieberman 2007), that, respectively, permit facial expressions, gesturing and articulate speech; *brain regions* such as Broca and Wernicke's area and *specific neurons* such as mirror neurons (Fadiga et al. 2000); *neuro-cognitive capacities* including memory, planning, theory of mind, and empathy (Christiansen and Chater 2016; Corballis 2002); *individual and sociocultural behavioral patterns* such as pointing, imitation, mimesis, pantomime, or learning and teaching (Dor 2015; Leavens et al. 2005; Racine et al. 2014; Goldin Meadow 2007; Zlatev 2014); and *properties of human languages*, including grammar (enabled by *recursion*), and the lexicon (characterized by *displacement*) (Chomsky 1965).

The question, therefore, becomes: *Given that we disagree, how can we circumvent defining language and still study its evolution?* Before we answer this question, we hone in on how the diverse definitions of language impact the various methodologies used to examine LE.

2.2 The Methodological Problem

Because there are so many disciplines involved, there exist plenty of fields and methodologies to examine how the diverse phenomena associated with language evolved. These include:

1. *Evolutionary developmental phenotype to genotype linkage studies* in so far as anatomical features, neurocognitive capacities, and behavioral traits are reducible to genes, scholars investigate this genetic variation and its transmission modes (Misyak and Christiansen 2011);
2. *(Comparative) paleontological research* on hominin anatomy (Tattersall 2014; Wood and Grabowski 2015);
3. *(Comparative) neurological and cognitive studies* that investigate the (homologs of) language-associated brain areas (Corballis 2002; Fadiga et al. 2000);
4. *(Comparative) sociocultural transmission studies*: language change and many of the behavioral and sociocultural traits that associate with language cannot be reduced to biological evolution (genes, anatomy or neurocognition), but we can study their sociocultural transmission modes; work that is facilitated by *historical/diachronic and comparative linguistics* as well as *linguistic and cultural phylogenetics* where scholars make use of *phylogenetic tree and network models* to map the diffusion and descent of languages or cultural artifacts (Atkinson et al. 2008; Mendoza Straffon 2016; Gray and Jordan 2000); and
5. *Classic linguistic studies* that demonstrate the peculiarities of human language (Chomsky 1965).

The above-listed fields and methodologies are further facilitated by *help sciences*, including:

6. *Ontogenetic research* encompassing *brain imaging studies* (Christiansen and Chater 2016) and *comparative psychological research* on normal and pathological human beings;
7. *Comparative primatological sciences* (Gontier and Pina 2014; Leavens et al. 2005; Matsuzawa 2001; Racine et al. 2014);
8. *Computational simulations* (Tamariz and Kirby 2016; Kirby 2016; Steels 2011) and in vivo *experiments* on iterated learning (Tamariz and Kirby 2016) and transmission chain studies (Mesoudi and Whiten 2008);
9. *Biological and cultural evolutionary theories* that explain the mechanisms of evolutionary change.

(1–3) involve *evolutionary biological studies* that enable *genealogical descent studies* on how language-related phenomena evolve and spread amongst *individuals, group and species* (Croft 2000; Mufwene 2001). (4) Involves *cultural evolution studies* that enable *geographic and ecological diffusion studies* on how behavioral and group traits associated with language, and the languages themselves, change/evolve and spread. And (5) encompasses *linguistic studies* that do not necessarily involve an evolutionary outlook, because we may study languages as closed synchronic systems.

Distinguishing biological from sociocultural evolution (9) has brought diversity into how we understand evolution. Some argue that cultural evolution follows Lewontin's (1970) *Darwinian principles* (Mesoudi and Whiten 2008), others say that biological and symbolic evolution *co-evolve* (Deacon 1997), and still others explain cultural evolution as a process *distinct* from biological evolution because the former can be directed or guided while the latter is blind (Boyd and Richerson 1985). Though these distinctions have proven useful, for they demonstrate that there are different *kinds* of evolution, it complicates clear identification of what domain, the biological, the cultural, or both, is involved in the evolution of specific traits.

It furthermore complicates immediate linkage of traits to the *mechanisms* whereby they evolve. Scholars used to straightforwardly endorse that language is an *adaptation* and that it evolved by means of *natural selection* (Pinker and Bloom 1990). But beyond natural and *sexual selection* (Pinker 2003), a myriad of mechanisms have now been invoked in LE, including *mechanisms of evo-devo*

(Dor 2015; Chomsky and Berwick 2016), the *ratchet effect* (Tomasello 2000); the *Baldwin effect* (Lachapelle et al. 2006); *hybridization*, etc. And from within cultural and linguistic phylogenetics, scholars have, besides classic patterns of *gradual descent with modification*, detected patterns of *punctuated equilibria, drift* and *reticulations or horizontal exchange* in how languages diffuse and diversify (Atkinson et al. 2008; Gray and Jordan 2000; Shijulal et al. 2010; Mendoza Straffon 2016).

Finally, the other help sciences (6–8) provide what Botha (2006: 132) calls *windows* of LE. A window is a phenomenon itself distinct from LE, that enables to draw inferences on how language *possibly* evolved. Examples include computer simulations, experiments, contemporary home signs, language acquisition, Pidgin and Creole languages, or cultural transmission of tool use by chimpanzees. But though computational simulations and in vivo experiments are helpful in generating and testing hypotheses on a possible context of use of certain traits, they are potentially biased toward certain premises. And inferences on evolution from ontogenetic (comparative) studies assume the *principles of continuity and uniformity*. That is, we must assume that the present is like the past. But biologists have long shown that ontogeny does not necessarily recapitulate phylogeny (see Gontier for a review 2006), and also environmental conditions might change over time. Simulating the original sociocultural and biological conditions, therefore, prove difficult (Gontier 2015). And per definition, windows differ from the *actual* units, levels and mechanisms wherefrom language evolved. Finding these is the main focus of the meta-methodology proposed here.

3 Toward a Unified Methodology: Applied Evolutionary Epistemology

Applied evolutionary epistemology (AEE, Table 1) is a *metatheoretical framework that understands evolution as the process whereby units evolve at certain levels of an ontological hierarchy by one or more mechanisms; and it provides three heuristics that enable the identification, examination, and evaluation of phenomena as either three* (Gontier 2010b, 2012).

I briefly explain how this universal methodology derives from how evolutionary biologists and evolutionary epistemologists study evolution as it occurs by means of natural selection; and I go on to demonstrate how AEE differs from the latter because it embraces an *extended synthesis*. Contrary to the Modern Synthesis, that defines evolution by Darwin's theory of natural selection, AEE does not single out one evolutionary theory. Instead, it remains neutral on the mode of evolution. It furthermore recognizes *unit, level, and mechanism plurality* as well as the need to establish *an, or multiple ontological hierarchies*.

3.1 Roots of AEE in the Units and Levels of Selection Debate and Evolutionary Epistemology

Evolutionary epistemology (EE) (Campbell 1974a; Bradie 1986) developed from research on how natural selection theory, that explains anatomical *form*, can, in addition, explain the evolution of sociocultural, linguistic and cognitive *behavior*. EE associated with the rise of ethology, sociobiology and comparative psychology which are disciplines that now evolved into the current field of evolutionary psychology. It also associates with evolutionary biology and philosophy of biology, where scholars have investigated how natural selection theory can be "universalized" (Dawkins 1983; Cziko 1995).

The founders of the Modern Synthesis understood evolution as the phenomenon where organisms (the *unit*) become naturally selected (the *mechanism*) by the environment (the *level*) if they are adapted to it (the *conditions*), while maladaptive organisms are naturally weeded out (the *assumptions*).

How then, have Neo-Darwinians defined these units, levels and the conditions whereby natural selection occurs? The answer is, differentially, because they never reached a consensus view. In fact, attempts to define either brought forth what we today call the units (Lewontin 1970) and levels (Brandon 1982) of selection debate.

Adherents of the Modern Synthesis take the *phenotype* as the basic unit of selection (Mayr 1997). But Dawkins (1982: 162) has argued that *genes* are the "true" units of selection because only these have "fecundity, longevity and copying-fidelity". The properties of genes and phenotypes, as units of selection, have since been "universalized" into *replicators*, i.e. "any entity in the universe of which copies are made" (Dawkins (1982: 162), and *interactors*, i.e. "an entity that directly interacts as a cohesive whole with its environment in such a way that replication is differential" (Hull 1980: 381). And Griesemer (2000:

Table 1 Applied evolutionary epistemology

Universal skeleton of evolution
Evolution occurs when *unit/s* evolve at *level/s* of an *ontological hierarchy* by *mechanism/s*
A derived universal evolutionary methodology
Studying evolution involves a search for units, levels and mechanisms, and locating them in an ontological hierarchy

363) has argued that most behavioral or cultural units of selection are *reproducers* (and see also Oyama et al. 2001). In sum, scholars originally tried to single out one true unit of selection, that they defined *intensionally* by listing essential properties, but today we find evidence for the ontological existence of all these entities. Consequently, we now need to recognize *unit-pluralism*: different entities can be units of selection.

The locus or *level* where a unit is subjected to natural selection is traditionally defined as the environment. This also used to be understood as a homogenous structure, one that coincides with the outer physical environment. But here too, evolutionary scholars have introduced a more nuanced view. The outer environment is not only made up of *non-living physical entities* such as rocks, soil or water, it is also roamed by *other organisms*, where through predator–prey relationships, organisms increase or decrease the selection of other organisms (Van Valen 1971). And beyond the external biotic or abiotic environment, organisms also have an *inner environment* that is heterogeneous (Lewontin 1970), simply because organisms are compositional structures made up of different body parts. A gene, for example, may be active in the heart but not the lungs, and this implies the presence of a selection process of the unit at certain but not other levels. Consequently, we need to recognize *level-pluralism*: units may evolve at different levels, and these levels are nowadays studied from within multilevel selection theory (Okasha 2005).

Turning to the *conditions* whereby natural selection operates, Darwin's evolutionary theory works on several *observable principles*. Organisms display variation in traits, offspring resemble their parents, and traits facilitate or disable survival and reproduction. Lewontin (1970) universalized these conditions or *Darwinian principles* into *differential variation, inheritance and differential fitness*. The Darwinian principles provide a *logical skeleton* or a *heuristic* of how natural selection operates, and it enables an expansion of Darwinian theory to research domains that surpass the study of biological form. Variation can be genetic but also behavioral or cognitive; behavioral "inheritance" does not require germline transmission because it happens through sociocultural transmission (learning and teaching); and differential fitness can be quantified by the number of offspring or by the success whereby behavioral traits remain part of a cognitive or cultural repertoire. Besides Lewontin's logical skeleton, we may also think of evolution by means of natural selection as a process that operates by a "blind variation and selective retention" heuristic, as Campbell (1974a), the founder of evolutionary epistemology, suggested. When we cannot point out units that vary blindly and that are selectively retained, then evolution by means of natural selection does not occur simply because the conditions for change are absent.

Turning to the *assumptions*, Darwin's selection theory assumes a *struggle for existence* due to a *scarcity of resources* and therefore a more likely elimination of the unfit, before they reach reproductive maturity. Adaptive organisms are attributed better *fitness values* because they spread their inheritable traits to future generations. Fitness thus provides a quantum whereby we measure *adaptation*.

The identification of units and levels of selection, and the identification of the working order or conditions of change whereby natural selection operates, function as the criteria whereby scholars argue that an entity evolves by means of natural selection. It also enables an implementation of natural selection theory into the sociocultural domain. But most of all, the recognition of unit and level plurality elicits the need to build *hierarchy theories of evolution* (Hull 1980) that deal with the ontological layeredness of the phenomena under study.

Genes, for example, can be selected at the genomic or organismal level during gene regulation, or they become selected at a group level (sex-linked genes, for example, only spread amongst specific members of a group, males or females), or at a species level (when they become fixed in a species, an example is the *FOXP2* gene to which we return later). Organisms, groups, and species together form an embedded *genealogical hierarchy* where the entities are linked through common descent (Tëmkin and Eldredge 2015). This hierarchy mimics artificial classification systems, with that important difference that we understand the genealogical hierarchy as composed of real entities, i.e. "biological individuals" that occupy space and time (Ghiselin 1975).

But genes can also become de/activated (and thus de/selected) by viruses or other species, and then the change is ecologically induced. Beyond the genealogical hierarchy, especially Tëmkin and Eldredge (2015) therefore differentiate an *ecological hierarchy* that is made up of organisms, populations, communities, ecosystems and the biosphere. While the genealogical hierarchy focuses on the genetic transmission of information, the ecological hierarchy allows for more general processes of matter and energy exchange. Finally, gene-regulation can be induced by abiotic factors, including carcinogens such as ultraviolet light.

Much debate exists on how we should define evolutionary hierarchies. Are they singular (Okasha 2005), dual (Tëmkin and Eldredge 2015) or multiple? Is causation reducible to the bottom (genetic) level (Dawkins 1982), or do processes of downward causation exist (Campbell 1974b), where upper levels alter lower levels of the hierarchy? The Baldwin (1896) effect, for example, enables an explanation, in Darwinian terms, of how social heredity occurs and this can, in turn, alter the trajectory of biological evolution. In other words, the sociocultural environment can impact biological evolution, something that has now been proven in what regards lactose tolerance at a genetic level that is due to prolonged consumption of milk at a cultural level, because of pastoralism.

When a dual, or multiple hierarchies are adhered to, the question becomes whether and how the hierarchies interact. How do hierarchies evolve and how do transitions between levels occur (Maynard Smith and Szathmáry 1995)? Providing answers to these questions is very much work in progress, but existing research demonstrates that developing adequate hierarchy theories is necessary just because there exists unit and level pluralism.

Finally, the layeredness of the evolutionary process makes us realize that entities may switch status. An organism, for example, may be a *unit* of selection at the *level* of the environment, but it may also be a *level* where replicators are selected. No principle of exclusivity can be maintained, units may be levels at one scale, and levels may be units at another.

Recapitulating, studying how evolution occurs by natural selection has involved research into the entities or *units* (replicators, interactors, reproducers) and the *levels* where these entities evolve. The recognition of unit- and level plurality, and considering that units may be levels at one scale and levels may be units at another scale, necessitates *hierarchy theories* that explain how units and levels interact and relate to one another. And beyond the units and levels of selection debate, scholars have also sought to define the principal *conditions* whereby selection operates, conditions they have often defined in the form of a heuristic, principles, or a logical skeleton. This defines the basic Neodarwinian methodology and in the next part, we will derive from this an even more universal methodology to study evolution, one that from within the extended synthesis also recognizes *mechanism plurality*.

3.2 Defining Units, Levels, and Mechanisms from Within an Extended Synthesis

Beyond natural selection, scholars working from within an extended synthesis (Pigliucci 2007) have identified numerous additional mechanisms and processes whereby evolution occurs, including drift (Kimura 1968), and hybridization, hereditary symbiosis, and lateral gene transfer (for an overview see Gontier 2015). Macroevolutionary scholars have detected patterns of punctuated equilibria that are induced by a variety of mechanisms (for an overview see Serrelli and Gontier 2015). And from within evolutionary developmental schools (Hallgrîmsson and Hall 2011), scholars have demonstrated that organisms display properties such as developmental plasticity, epigenetic inheritance, and genetic assimilation that all may induce evolutionary change. These theories have identified new units and levels, not of natural selection *per se*, but units and levels of those particular mechanisms and processes (Gontier 2010a, b, 2012).

Put negatively, definitions of units and levels of evolution are often biased toward natural selection theory. Put positively, we need not throw away the baby with the bathwater, because the endeavor whereby Neo-Darwinians have tried to universalize natural selection theory can and is setting the example for how we can now examine and universalize extended evolutionary theories. Scholars researching an extended synthesis continue to search for *units* whereon and *levels* whereat mechanisms are active, and they also try to identify the *conditions* whereby non-selectionist mechanisms induce evolutionary change.

On a meta-level, we can derive an even more *universal skeleton* and *methodology* from how scholars study evolution. AEE's universal skeleton states that *when evolution occurs, units evolve at certain levels of an ontological hierarchy by certain mechanisms*. This appears to be a minimum requirement for any kind of evolution to occur, and in previous work, I have proposed a more *pragmatic* and *neutral* way whereby we can identify units, levels, and mechanisms of any and all kinds of evolution (Gontier 2010a, b). Instead of providing intensional/essential definitions of either three (as has been done in the past), I propose two alternative ways to define phenomena as units, levels, and mechanisms of evolution. One definition is *extensional*, the other *ostensive* (Table 2).

Table 2 Ostensive and extensional/denotative definitions of units, levels and mechanisms and their associated epistemic questions

	Epistemic question	Extensional/denotative definition	Ostensive definition (definition by pointing)
Unit	*What*	*The entity that evolves*	X is a unit if one can minimally point out one level where x evolves, and one mechanism whereby x evolves
Level	*Where*	The *locus* where evolution occurs	X is a level if one can minimally point out one unit that evolves by minimally one mechanism at x
Mechanism/process	*How*	The *means/conditions* whereby evolution occurs	X is a mechanism if one can minimally point out one unit that evolves at one level by means of x

Extensional definitions say what a phenomenon denotes. In our case, a *unit* stands for the *entity that evolves*, the *level* designates the *locus or place where the unit evolves*, and the *mechanism* indicates the *conditions whereby the change of units at levels occurs*. The extensional definitions furthermore link to specific epistemic questions. The *unit* is the *what* of evolution, the *level* is the *where*, and the *mechanism* is the *how*.

Ostensive definitions encompass an identification of the phenomenon referred to by demonstrating its existence. This often involves pointing out where phenomena belong in an ontological hierarchy. As such, a *unit* can be identified by pointing out the level where and the mechanism whereby it evolves; a *level* can be identified by pointing out a unit that evolves at this level and a mechanism whereby this unit evolves at that level; and a *mechanism* is recognized as such when we can point out one or more units whereon it is active at certain levels.

AEE recognizes unit, level and also *mechanism plurality*. Biological and sociocultural evolutionary scholars are currently demonstrating that units (the elements that evolve) and levels (the place where evolution occurs) are often *simultaneously* subjected to more than one evolutionary mechanism (the conditions whereby evolution occurs). Theorizing on mechanisms also no longer justifies adherence to any principle of exclusivity. A gene, for example, that is subjected to positive selection at both the genetic and environmental level, can also become transmitted horizontally, by hybridization or lateral gene transfer.

4 Implementing AEE into Evolutionary Linguistics

We first examine how implementing AEE into evolutionary linguistics need not start from scratch because scholars have, albeit often implicitly, already tackled questions on hierarchies, units, levels, and mechanisms. Secondly, we present the three AEE-heuristics that enable a more explicit identification, examination, and evaluation of units, levels, and mechanisms of LE, and we explain how they will enable to establish hierarchies of LE.

4.1 Possible Units, Levels, and Mechanisms of LE

Chomsky and co-workers' I- and E-language distinction has dealt with questions of units, levels, and hierarchies. I-language contains the FLN and FLB and is part of an "organism-internal environment," while they divide the "external environment" into a hierarchy made up of social, cultural, physical and ecological layers or realms (levels). Amongst examples of the FLB-sensory-motor system, Hauser et al. (2002: 1573) included vocal imitation and invention, neurophysiology of action-perception schemes, discrimination of sound patterns, biomechanisms of sound production, and modalities of language production and perception. Examples of the FLB-conceptual-intentional system include theory of mind, the ability to acquire non-linguistic conceptual representations, referential vocal signals, imitation, and voluntary control of signal production (Hauser et al. 2002: 1573). The latter may all be understood as possible units of language evolution. Finally, Berwick and Chomsky (2016) especially point toward evo–devo mechanisms when they argue that the capacity to merge possibly results from a prolonged activation of an enhancer sequence that underlies the development of neural fiber tracts that connect dorsal and ventral brain areas.

In a very real sense, most evolutionary linguists are per definition Neodarwinian evolutionary epistemologists, because following Pinker and Bloom (1990), they have endorsed the view that language evolved by means of natural selection. Embracing universal Darwinism (Dawkins 1983) or universal selectionism (Cziko 1995) has proven useful in evolutionary linguistics because scholars have modeled how *replicators* (Szathmáry 2006) and *memes* of sociocultural and linguistic evolution, such as the *lingueme* (Croft 2000) become faithfully transmitted. Nonetheless, the approach has limitations because most linguistic units are not faithfully replicated. At most, they reproduce through social practices such as teaching and learning (Mesoudi and Whiten 2008), and cultural transmission experiments have demonstrated that this transmission occurs via more loosely defined Darwinian principles (Steels 2011; Tamariz 2014; Tamariz and Kirby 2016). Most importantly, the scholars involved have tackled the question of transmission at an individual and group level.

But more mechanisms have been implicated. Scholars have demonstrated that language diffusion occurs by drift (Jespersen 1909; Greenberg 1960; Sapir 1921), that language evolution/change can occur both slowly and rapidly (Gray and Joran 2000; Atkinson et al. 2008), and that many traits associated with the biological capacity to evolve a particular language, are not adaptations, but exaptations (Gould and Vrba 1998; Tattersall 2014) or neutral traits (Kimura 1968). Some are even maladaptive. Our supra-laryngeal vocal tract, for example, might enable us to produce a rich vocal palate, but it also facilitates choking (Lieberman 2007).

A swift consideration of the literature, therefore, provides a series of possible units, levels, mechanisms, and hierarchies (Table 3). And as the brief exemplification shows, also hierarchy theories are numerous, simply because our epistemologies can take on different viewpoints of ontology. Amongst other, we can develop hierarchies based upon anatomical, genealogical, sociocultural/

Table 3 Possible units, levels, evolutionary mechanisms/processes and hierarchies involved in LE

Units	Levels	Evolutionary mechanisms and processes
Genes (e.g. the *FOXP2* gene) and gene clusters?	**Organismal (anatomy-based) hierarchy:**	**Natural selection? Sexual selection? Neutral evolution/ drift?**
Brain areas that underlie the FLB (Broca, Brodmann's area 44, 45, Wernicke) and its subcomponents (e.g. modules or specific neurons such as mirror neurons)?	e.g. genetic, genomic, cellular, embryological, neurological, behavioral phenotype	*(Relates to discussions on adaptations/neutral traits/exaptations)*
Cognitive capacities (e.g. intentionality, ToM, memory, empathy, emotions, hand-eye coordination, navigation in time and space enabled by foresight, goal-oriented behavior, and planning)?	**Genealogical (descent-based) hierarchy:**	**Reticulate evolutionary mechanisms** (e.g. lateral gene transfer, symbiosis, hybridization)?
Anatomical traits involved in orofacial movements and gesturing (e.g. the SVT and its subcomponents, hand bones, muscular structures)?	e.g. organism, group, species?	**Mechanisms of evo-devo and epigenetics?**
Behavioral capacities (e.g. facial expressions, pointing, co-verbal gesturing)	**Sociocultural/Ecological hierarchy (extra-genetic):**	**Macroevolutionary processes?** (e.g. the turnover pulse hypothesis, Red Queen hypothesis, stasis)
Linguistic traits (e.g. displacement, recursion, morpho-syntax)?	organism, language groups/communities, language families, super-families?	**Physical processes** (e.g. climate change)
Sociocultural phenomena (e.g. linguemes, idiolect, dialect, sociolect, a specific language)?	**Physical hierarchy (abiotic)?**	*(Relates to discussions on the nature of mechanisms, the mode and tempo of evolution, and the means whereby information is transmitted)*
Precursors to language (e.g. protolanguage and its subcomponents)?	*(Relates to debates on multilevel evolution and ontological hierarchies; gene-cultural co-evolution or the existence of a non-biological "super-organic")*	**Cultural mechanisms** (e.g. the Baldwin effect, ratchet effect, operant conditioning, classic conditioning, observational learning, learning by imitation, direct instruction, emulative learning?)
(Relates to debates on multi-unit evolution and ontological hierarchies)		*(Relates to the distinction between biological and cultural evolution and discussions on the nature of mechanisms)*

ecological and physical hierarchies (but for a more elaborate view, see Gontier 2017).

Nonetheless, evolutionary linguists have often tackled core evolutionary epistemological questions in the margins of their research instead of bringing them to the forefront. Instead, they have given preference to theory formation. Such is understandable, because asking about units, levels, and mechanisms, and establishing the hierarchy of language-related phenomena is all but evident.

How, for example, do we study the evolution of the supra-laryngeal vocal tract (SVT) that enables speech? Do we reduce it to a genetic level and search for the genes that make up the SVT, or do we study the anatomy of the SVT, the brain regions that control it, or its products (sounds)? At present, scholars walk all research avenues, and all provide valuable data. The SVT furthermore is a compositional structure that is decomposable into sub-units, including the lips, teeth, palate, tongue, velum, epiglottis, pharynx, the hypoglossal canal and its nerves, and the hyoid bone. Here too, scientific practices demonstrate that all these structures can and have been studied individually, all somewhat trace back to genes and specific brain areas that control their function, and all underlie behaviors that are irreducible to genes. This necessitates a hierarchical understanding of the structures. And similarly, the SVT is but one subcomponent of a larger phenomenon we call language. Language can therefore but be a super-unit that is itself decomposable into several sub-units.

All this implies unit-pluralism, level-pluralism, and mechanism-pluralism, and the question becomes how we can structure the data into an, or multiple hierarchies, because, as the middle column of Table 3 demonstrates, options are diverse.

4.2 The Three AEE-Heuristics that Enable an Identification, Examination and Evaluation of the Units, Levels and Evolutionary Mechanisms of LE

How then does AEE enable a structuring of the data? In what follows, we demonstrate how AEE can generate, constrain and help evaluate research avenues by following three heuristics that help identify the units, levels, and mechanisms of LE.

AEE circumvents intentional definitions because it stands *neutral* toward language definitions, and it avoids intensional definitions of the units, levels, and mechanisms involved. Instead, it asks to demonstrate, ostensively, that an entity under examination is a unit by pointing out the level whereat and the mechanism whereby it evolves. AEE is a *pragmatic* way to unite the various datasets and it also enables one to distinguish *windows* from the *actual* phenomena involved in LE. Successfully implementing the heuristics will furthermore provide better insight into how the hierarchies associated with LE take shape.

Suppose then that we have an x that is presumed to be relevant for LE. X is relevant for LE if and only if we can prove it is at minimum either a unit, level or mechanism of LE. The units, levels and evolutionary mechanisms that allow language to evolve can be found by following the heuristics set out in Table 4.

5 An In-Depth Analysis of the Unit-Heuristic

First, we give a full version of the unit-heuristic and then we walk through the heuristic point by point.

5.1 Full Version of the Unit-Heuristic

Table 5 gives an elaborate version of the unit-heuristic.

5.2 Walking Through the Heuristic

How then, can we investigate whether x is a unit of LE?

5.2.1 The Question Mark-Phase

(1) When we do not know without examination of x that it is a unit of LE, we recommend to try and prove that x is a unit, by going to the Yes-phase and answering questions 2 and 3. As said, x is a unit of LE if one can minimally point out one level where x evolves (2), and one mechanism whereby x evolves (3). In the uncertain situation, one example of either suffices to demonstrate that x is indeed a unit, and then you may move on to the yes-phase. When neither one level (*2.a.*) nor one mechanism (*3.a.*) are identifiable, the heuristic directs you to the no-phase (*9*).

When uncertain about x, trying to prove the yes-phase is preferred over the no-phase (*9.*) because the no-phase asks whether x is a level and/or an evolutionary mechanism (*9.a.*). Identifying x as a level or a mechanism, however, does not *a priori* exclude x from being a unit. An *organism* may simultaneously function as a *unit* that evolves by means of natural selection at the level of the environment, and that same organism may be a *level* where units such as genes are targeted by selection.

5.2.2 The Yes-Phase

If you skipped the question mark-phase and immediately argued that x is a unit of LE, then this action is only *justified* if minimally *one* level (*2.*) and minimally *one* mechanism (*3.*) was identified where and whereby x evolves (because if x evolves, it must evolve somewhere and somehow).

Table 4 Abbreviated version of the unit, level and mechanism heuristics (read from left to right and top-down)

IS X A *UNIT* OF LE?

?	**Try to prove that x is a unit of LE** (1 example suffices); Go to yes.		
YES	**Where?** Identify the **level/s** where x evolves	**Not one level found?** X is not a unit; Go to no.	
		One/multiple level/s? *(Justification)*	**How, by which mechanism/s** did x evolve? *(Justification)*
	Since when?	When did x first originate in time and **when did x become a unit of LE?**	
	How does x **interact** with other units?	Is x divisible into one or more **sub- or super-units**? If so, are they **also units** in LE?	
	Is x also a **level** and/or **mechanism**?	**? & yes:** Go to the level and/or mechanism-heuristic.	
	How **relevant** is x?	Is x **sufficient and/or necessary** for LE or for theories thereof?	
NO	If not a unit, is x a **level** and/or a **mechanism**?	**? or Yes:** Go to the level and/or mechanism-heuristic.	
		No: Is x a **window** of LE?	**Yes: Treat x accordingly**.
			No: Treat x as **irrelevant** for LE.

IS X A *LEVEL* OF LE?

?	**Try to prove that x is a level of LE** (1 example suffices); Go to yes.		
YES	**How many/what units** evolve at x?	**No units are identified?** X is not a level; Go to no.	
		One/multiple unit/s? *(Justification)*	**By which/How many evolutionary mechanisms** did the unit evolve at x? *(Test)*
	What is the **ontological status** of x?	**Is x an abstract notion that facilitates theory formation, or an existing entity ?**	
	Since **when**?	**Locate the origin of x in time or indicate when it becomes necessary to invoke x** as an abstract notion in LE theories.	
	How does x **interact** with other levels?	Is x divisible into **sub- or super-levels?** If so, are they also levels in LE?	
	Is x also a **unit** and/or **mechanism**?	**? & yes:** Go to the unit and/or mechanism-heuristic.	
	How **relevant** is x?	Is x **sufficient and/or necessary** for LE or for theories thereof?	
NO	If not a level, is x a **unit** and/or **mechanism**?	**? or Yes:** Go to the unit and/or mechanism-heuristic.	
		No: Is x a **window** of LE?	**Yes: Treat x accordingly**.
			No: Treat x as **irrelevant** for LE.

IS X AN *EVOLUTIONARY MECHANISM* OF LE?

?	**Try to prove that x is an evolutionary mechanism involved in LE**; Go to yes**.**		
YES	On how many **units** is x active?	**Not one unit:** x is not an evolutionary mechanism involved in LE.	
		One/multiple unit/s. *(Justification)*	**At how many levels is x active?** *(Test)*
	How does x work?	**What conditions need to be met for x to occur?** *(Requires universal heuristics of the working order of the mechanism.)*	
	Since **when**?	**Locate in time when these conditions are met** regarding each unit and each level**.**	
	How does x **interact** with other mechanisms?	Is x divisible into **sub-or super-mechanism/s?** If so, are they also mechanisms of LE?	
	Is x also a **unit** and/or **level**?	**? & yes:** Go to the unit and/or level-heuristic.	
	How **relevant** is x?	Is x **sufficient and/or necessary** for LE or for theories thereof?	
NO	If not a mechanism, is x a **unit** and/or **level**?	**? or Yes:** Go to the unit and/or level-heuristic.	
		No: Is x a **window** of LE?	**Yes: Treat x accordingly**.
			No: Treat x as **irrelevant** for LE.

Table 5 Is x a unit in/of language evolution (LE)? (read from left to right and top-down)

?	**1. Try to prove that x is a unit of LE:** Go to yes and **try and answer questions 2 and 3** (1 example of each suffices).				
Y E S	**2. Where, at what level/s does x evolve?** Identify new level/s or examine whether x evolves at known levels.	**2.a. Not one level is identified:** X is not a unit, go to no.			
		2.b. There are newly identified level/s of LE: Investigate these from within the level-heuristic.			
		2.c. One level? Go to 3.			
		2.d. Multiple levels? Identify all, then go to 3.			
	3. How, by which mechanism/s does x evolve at each identified level? Identify new mechanism/s or examine whether x evolves by known mechanisms. *2+3 justify that x is a unit of LE.*	**3.a. Not one mechanism is identified:** X is not a unit, go to no.			
		3.b. There are newly identified mechanism/s of LE: Investigate these from within the mechanism-heuristic.			
		3.c. One mechanism?	**3.c.1. X evolves by one mechanism at one level:** Explain why there is mechanism and level exclusivity.		
			3.c.2. X evolves by one mechanism at multiple levels: Explain how a single unit evolves at multiple levels, how the same mechanism is active on the same unit at multiple levels, and how the different levels interact/relate to one another regarding this unit. *Requires multilevel evolution theory.*		
		3.d. Multiple mechanisms? Identify all.	**3.d.1. X evolves by multiple mechanisms at one level:** Explain how different mechanisms act simultaneously on the same unit at one level, and how the different mechanisms interact/relate to one another regarding this unit. *Requires multi-mechanism theory.*		
			3.d.2. X evolves by multiple mechanisms at multiple levels: Explain how different mechanisms act simultaneously on the same unit at multiple levels, and how the different mechanisms interact/relate to one another regarding this unit. *Requires multi-mechanism and multilevel evolutionary theory.*		
	4. Since when is x a unit in LE?	**4.a. Locate the origin of x in time.**			
		4.b. Locate in time when x became a unit of LE at each level where it is a unit independently.			
		4.c. Has x constantly (from 4.b. onward) been a unit of LE? *Depends on the continuity and invariability of the level/s where it is a unit and the evolutionary mechanism/s whereby x evolves.*	**4.c.1. ?**	**4.c.1.1. Try to prove that is was inconstantly a unit of LE:** Go to no (1 example suffices).	
			4.c.2. No. Implies that level/s or mechanism/s, or both, are inconstant.	**4.c.2.1. Specify variations in time:** Demonstrate when x was not, and again became a unit at a certain level (if it did); and/or when it did not evolve by a certain mechanism and again evolved by it (if it did). *= How to prove no*	**4.c.2.1.1. Treat each variation of x as a possible different unit of LE:** Start from unit onward for each variation.
					4.c.2.1.2. Has each variation of x conjointly been a unit in other kinds of evolution? (E.g. the evolution of life in general, the evolution of mankind, brain evolution, etc.).
				4.c.2.2. Impossible to specify variations: X has constantly been a unit of LE, go to yes.	
			4.c.3. Yes. Implies that both the level/s and the evolutionary mechanism/s are constantly present and acting upon x. *Justifies that x is a constant unit.*	**4.c.3.1. Specify whether x has conjointly been a unit of other kinds of evolution** (E.g. the evolution of life in general, the evolution of mankind, brain evolution, etc.).	
	5. How does x interact with other units? Compare with all known LE units. *Requires hierarchy theory.*	**5.a. Is x divisible into sub-units?**	**5.a.1. Yes:** Are these sub-unit/s also unit/s of LE?	**5.a.1.1. ? or Yes:** Repeat from unit onward for every sub-unit. *Will allow to identify new units, exclude entities that are not units, and it will enable hierarchy formation.*	
				5.a.1.2. No: Are they units in other kinds of evolution?	
			5.a.2. No.		
		5.b. Can x be absorbed into super-unit/s?	**5.b.1. Yes:** Are these super-unit/s also units of LE?	**5.b.1.1. ? or Yes:** Repeat from unit onward for every super-unit. *Will allow to identify new units, exclude entities that are not units, and it will enable hierarchy formation.*	
				5.b.1.2. No: Are they units in other kinds of evolution?	
			5.b.2. No.		
	6. Is x conjointly a level of LE?	**6.a. ? & yes:** Try and treat x as a level, go to the level-heuristic.			
		6.b. No.			
	7. Is x conjointly a mechanism of LE?	**7.a. ? & yes:** Try and treat x as a mechanism, go to the mechanism-heuristic.			
		7.b. No.			
	8. What is the relevance of x?	**8.a. Is x sufficient for LE?**	**8.a.1. Yes:** Explain why there are other units involved in LE (if there are).		
			8.a.2. No: Explain why it is insufficient to explain LE.		
		8.b. Is x necessary for LE?	**8.b.1. Yes:** Treat x as a general (universal) unit of LE that needs to be present during a certain period in LE and that needs to be accounted for in all LE-theories.		
			8.b.2. No: Treat x as a peculiar/particular unit of LE and as a unit that does not necessarily need to be accounted for in all LE-theories.		
N O	**9. Is x conjointly a level and/or mechanism of LE?**	**9.a. ? or Yes:** Go to the level and/or mechanism-heuristic.			
		9.b. No. Is x a window?	**9.a.1. Yes:** Treat x accordingly.		
			9.b.1. No: Treat x as irrelevant for LE until proven otherwise.		

But during the yes-phase, research cannot end here, because x might be evolving by *multiple* mechanisms at *multiple* levels. A *gene* can simultaneously be targeted by selection at the *genomic* and the *organismal level*; or a gene might be evolving by *drift* at a genomic level, while it might become transmitted through *hybridization*.

Beyond identifying x as a unit, a series of other questions are generated by the heuristic that enable a more thorough examination and evaluation of the unit x. The yes-phase is therefore divided into three sub-phases: an *identification-, a question generating and constraining-, and an evaluation-phase*.

5.2.3 The Identification-Phase (2–3)

During the identification-phase, we ask *where* x evolves (leading to level-identification) and *how* x evolves (enabling mechanism-identification), and as said, both questions need to be answered to prove or *justify* that x is a unit of LE. We now turn to these questions one by one.

(2) The *where*-question asks about the level or locus where x is a unit of LE. It is identifiable in two ways: either you investigate whether x is a unit at known levels of LE, or you identify new level/s where x evolves (by a certain mechanism). Put negatively, x can only be excluded from being a unit of LE if it has been proven not to be a unit at *every* recognized level. Moreover, the status of "not being a LE-unit" must be re-evaluated every time a new level is discovered. Finally, identifying a level (*2.c.*) only partially justifies that x is a unit, because also the mechanism/s whereby x evolves at that level need to be identified (*3.*).

During the identification-phase, you should aim at exhaustion and identify *all* levels where x evolves. When we cannot identify one level where x evolves, then x is not a unit (*2.a.*). When new levels are identified, these need to be examined independently from within the level-heuristic (*2.b.*). As such, the unit-heuristic is not only a device designed to test or identify units, it additionally allows to identify new levels.

Regulatory genes, for example, are highly conserved throughout the genome, generally indicating strong selection pressures for preservation. The question is where, at what level/s such genes are targeted by selection. The *FOXP2* gene (Lai 2000, 2001), for example, is a regulatory gene indicated to facilitate orofacial movements that underlie articulate speech, but it is also active during the formation of the heart and the gut. All might be levels, i.e. loci where the gene becomes targeted by selection. Proving that the *FOXP2* gene is targeted by selection at the level of the gut, however, will not prove that the gene is a unit specifically involved in LE. For that, we should prove that it is targeted by selection at, let's say, the level of "speech", or the "SVT" that enables speech, or the "language brain regions" that control the movements of the SVT.

For one, this example demonstrates the need to develop adequate hierarchy theories whereby we classify data on units and levels, an issue we return to under question 5 of the heuristic. Secondly, it demonstrates that entities are often multifunctional. The *FOXP2* gene might be evolving at both the level of the gut and the supra-laryngeal vocal tract, but these structures do not appear to entertain any direct relation, and the gene is probably regulating different proteins at these different loci. This question on (functional) variation is further analyzed under 4.

(3) The *how*-question asks about the mechanism/s whereby x evolves at each identified level. Here too, you can examine whether x evolves by known evolutionary mechanisms, or you can identify a new mechanism of LE that then needs to be tested from within the evolutionary mechanism-heuristic (*3.b.*). Put negatively, a search for mechanisms is only exhausted when x has been examined to evolve by all known mechanisms involved in LE.

X possibly evolves by one (*3.c.*) or more (*3.d.*) evolutionary mechanisms, at one (*2.c.*) or more (*2.d.*) levels leading to the following four possible outcomes:

1. The unit x evolves by one mechanism at one level (*3.c.1.*), and then we need to explain why there is mechanism- and level-exclusivity;
2. X evolves by one mechanism at multiple levels (*3.c.2.*), and then we need to explain how one unit evolves at multiple levels by the same mechanism as well as how the different levels interact (*2.b.1.*)—this relates to multilevel evolution theory;
3. X evolves by multiple mechanisms at one level (*3.c.3.*), and then we need to explain how different mechanisms act simultaneously on the same unit at one level, as well as how the different mechanisms interact (if they do)—this relates to multi-mechanism evolution theory;
4. X evolves by multiple mechanisms at multiple levels (*3.c.4.*), and then we need to examine how different mechanisms act simultaneously on the same unit at multiple levels, as well as how the different mechanisms and the different levels interact with one another regarding this unit (if they do)—this requires both multi-mechanism and multilevel evolutionary theory.

Pointing, for example, is often implicated in gesture-first or multimodal theories on LE. Butterworth (2003), has hypothesized that pointing is genetically determined and that it evolves by means of natural selection; Leavens et al. (2005) argue that pointing is part of the phenotypic, behavioral repertoire of primates and that diverse environmental stimuli trigger the behavior epigenetically; and Tomasello (2000) understands it as a form of cultural learning enabled by the ratchet effect. If either one of them is correct, and the other is wrong, this would exemplify outcome 1, and then pointing either evolves at a genetic, a behavioral or a cultural level, respectively by natural selection, epigenetics or the ratchet effect. If all are right, their theories on pointing exemplify outcome 4, and then we need to explain how pointing evolves at all these levels simultaneously, and by a diversity of mechanisms.

My aim here is not to solve the issues raised. The authors that make the claims are better able to do so. Instead, the heuristic provides a structure wherein we can frame these questions. Answers will require applied evolutionary epistemology that combines unit-, level-, and mechanism plurality with hierarchy theory.

5.2.4 The Question Generating and Constraining-Phase (4–7)

When questions 2 and 3 are answered, you have identified x as a unit of LE. At this point, the heuristic becomes an investigative tool and provides you with questions that systematically examine when x evolved, whether x portrays variation, which variations are relevant to LE, and how x situates itself within the evolutionary hierarchy that underlies LE.

(4) The first question that is generated is the *since when* question. Having proven that x is a unit of LE, it becomes necessary to ask if x, from its origin onward, has always been a unit of LE. Do this by first locating the origin of x in time (*4.a.*), and secondly by examining if this date coincides with the origin of x as a LE unit for each level where it is a unit (*4.b.*).

This approach allows you to detect variations (in both function and form), and it helps to solve ongoing debates on whether x is an adaptation "for" LE (Dawkins 1982; Pinker and Bloom 1990) or an exaptation (Gould and Vrba 1998; Hauser et al. 2002; Tattersall 2014). When the date at which x originated differs from the date at which x became a unit in LE, then x is an exaptation. X is an adaptation only when the dates converge (see Gontier 2006 for a discussion).

All mammals, birds, and amphibians, for example, possess tongues, but the tongue cannot be a unit in LE from the time of amphibians onward, since they do not display language (although many have complex communication systems).

Recognizing that language is a heterogeneous phenomenon and thus that it involves a multiplicity of units, levels, and mechanisms, necessitates us to consider the dynamics of these elements. Not all are present, all the time and everywhere, and we need to find a way to cartography these dynamics. Question *4.c.* digs further by asking whether x, from the moment it became a unit of LE onward, has constantly remained a unit of LE. When we cannot straightforwardly provide an answer (*4.c.1.*), it is recommended to try and prove that it has inconstantly been a unit of LE (*4.c.1.1.*). One counterexample suffices to prove that x has been an inconstant unit.

Demonstrating that x is an inconstant unit of LE entails demonstrating one of three things (*4.c.2.*): either the level/s where x evolves are inconstantly present; or the evolutionary mechanism/s whereby x evolves are inconstantly active upon the unit; or both the level/s and the evolutionary mechanism/s are inconstant. If either of these three options is the case, the variations need to be specified (*4.c.2.1.*). It thus needs to be specified when x was not a unit at a certain level and again became a unit (if it did); and when x did not evolve by a certain mechanism, and again evolved by it (if it did).

The *FOXP2* gene was subjected to a *selective sweep* (Enard et al. 2002), but how did it evolve before this sweep? At present, we don't know. In general, selection only happens when there is a struggle. When the environmental conditions become less harsh, selection might turn into drift and any ongoing selection process will be destabilized. And a *lexicon*, for example, might evolve at the *level* of the population when population size makes it necessary to communicate adequately to as many as possible (Dunbar 1998), but the environmental conditions might not always have allowed for big groups. What happened if over certain periods of time the group became smaller, due to e.g. glaciation events?

Specifying these variations in time will also enable scholars to identify elements that used to be units of LE, but have since stopped to be units (either because the unit x no longer exists, or because x is no longer a unit of LE). And this implies that studying LE does not necessarily end when all current units of LE are exposed.

Each variation in time of the unit needs to be treated as a possible different unit, from unit onward (*4.c.2.1.1.*), and it is interesting to investigate whether each variation has likewise been a unit in other kinds of evolution (*4.c.2.1.2.)*. This will further enable to make clear whether x has been a unit that arose specifically in a LE context or not.

The origin of the *FOXP2* gene (Lai et al. 2000, 2001; Vargha Khadem et al. 2005), for example, outdates the origin of our species. It is a very old gene that arose from opisthokonts (animals and fungi) onward and different species, such as mice, song birds, and chimpanzees, exhibit species-specific *variations*. The gene can evidently not be considered a unit in human LE in these different, older species. Nonetheless, it might be a unit in mice communication because it has been proven to underlie their ultrasonic vocalizations, and the gene is active during songbird learning (see Berwick and Chomsky 2016 for an overview). Research originally suggested that the human-specific variant of the *FOXP2* gene originated some 200,000 years ago (Enard 2002; Zhang et al. 2002), and in comparison with the chimpanzee orthologue, it underwent 2 specific amino acid changes that have since been the target of positive selection. Krause et al. (2007) later showed that Neanderthals shared the same variation, and conjectured that the variant might be shared by both species' last common ancestor, pushing the origin of the amino acid substitutions back to 300–400,000 years ago. It is this variation common to both species that is likely involved in the evolution of orofacial movements that facilitate articulate speech (for a discussion, see Gontier 2008). The evolution of ultrasonic communication in mice, or songbird learning, are examples of other *kinds* of evolution where variants of the gene serve as a unit. As such, the heuristic enables one to distinguish these kinds of evolution from the ones actually involved in LE.

Similarly, the voice, for example, might be a unit of natural selection at the level of speech, and it might simultaneously be a unit of sexual selection at the level of the species. But the voice is irrelevant for the evolution of opposable thumbs.

If it has been impossible to specify variations, x has constantly been a unit of LE (*4.c.3.1.*). Or, stated otherwise, it is justified to call x a constant unit (if you skipped the question mark-phase and went immediately to yes), only if it can be proven that the level/s and the mechanism/s were constant (*4.c.4.*). Also in this case, it is interesting to see whether x has been a unit in other kinds of evolution (*4.c.4.1*).

(5) The next question continues to tackle the problem of variation, not by investigating the continuous nature of the unit, but by asking *how the unit x interacts with other units of LE*. Answers require the establishment of a hierarchy of units. The first sub-question asks whether the unit is divisible into several sub-units (*5.a.*). If so, these sub-units need to be investigated as possible independent units from within the unit-heuristic (*5.a.1.*); if not, they need to be examined as possible units of other kinds of evolution (*5.a.1.2.*).

Again turning to the *FOXP2* gene, this gene encodes for the FOXP2 protein that contains the fixed forkhead-box DNA-binding domain responsible for gene regulation, as well as a large and highly variable polyglutamine tract, a zinc finger, and a leucine zipper. The latter are sub-units of the protein (and thus the gene), and so we need to investigate these as possible units of LE in their own right, and how they are possibly involved in other kinds of evolution.

It is especially the FOX domain that is of interest to evolutionary linguists because mutations in this region link to orofacial deficits required for articulate speech. In non-pathological individuals, the transcription factor regulates expression of the *CNTNAP2* gene that encodes for neurexin, a presynaptic protein involved in connecting neurons at the synapses; the *CTBP1* gene that encodes for a C-terminal-binding protein 1 that functions as a repressor by switching genes of; and the *SRPX2* gene that underlies synapse formation in the cerebral cortex. All sub-units of the FOXP2 protein thus appear to be units involved in brain evolution in our and other species. Mutations in the *CNTNAP2* gene are implicated in Gilles de la Tourette syndrome (Verkerk et al. 2003), schizophrenia, and autism. Variations of the polyglutamine tract are implicated in speech sound disorder in Chinese populations (Zhao et al. 2010). SRPX2 reduction is linked to impairments in ultrasonic vocalization in mice (Sia et al. 2013). Following the heuristic provides a useful tool for identifying these variations, examining their relevance for LE, and identifying which are possibly involved in other kinds of evolution.

The second sub-question asks whether the unit under examination is absorbable into one or more super-units (*5.b.*), and if so, whether these, in turn, are independent units of LE (*5.b.1.*), or other kinds of evolution (*5.b.1.2.*).

To continue our example of the *FOXP2* gene (Lai et al. 2000), we know that it is located on chromosome 7 (7q31, at the SPCH1 locus). Chromosome 7 is a super-unit where the *FOXP2* gene is part of, simply because it contains numerous genes, and the heuristic, therefore, recommends an independent investigation of it. This, in turn, will justify a full decomposition of the chromosome into its various genes (its sub-units). Chromosome 7, in turn, forms part of the human genome that can be regarded as an example of a super-unit. A mere examination of the *FOXP2* gene as a possible unit of LE, thus justifies a full screening and independent investigation of the genome for possible units of LE; and it enables a better categorization of which sub- and super-units are actually relevant for LE and what entities are part of other kinds of evolution (such as the evolution of the brain, synaptic connections, ultrasonic vocalization, etc.).

The question on sub- and super-units furthermore helps in establishing a workable hierarchy of units that link epistemology (theory formation) to ontology (reality). Units are best regarded as Matruskas, structures that are both decomposable into smaller substructures and composable into larger superstructures. Asking about sub- and super-units will expose new units of LE that in turn need to be investigated independently, from unit onward. For sure, this is not an easy task, but it is nonetheless a necessary one.

Sign language, for example, is decomposable into hand gestures, facial gestures etc., and grouped into non-verbal, natural languages that differ from spoken ones. But where do we classify a behavior such as pointing? For one, pointing is demonstrably present in primate communication systems, although functional variation occurs (Tomasello 2000). Secondly, scholars who endorse multi-modal theories on LE or gesture-first theories (Corballis 2002; Leavens et al. 2005; Zlatev 2014) often implicitly understand or classify pointing, as a (sub-)unit of non-verbal communicative behavior. Non-verbal communicative behavior, in turn, might be part of a (type of) protolanguage (Bickerton 1990). But, and thirdly, pointing may also be considered a (sub-)unit in co-verbal gesturing, and, as the name implies, co-verbal gesturing implies the accompaniment of speech (Goldin-Meadow 2007). As such, pointing can be a unit in primate communication (Leavens et al. 2005; Tomasello 2000), protolanguage (Wacewicz and Zywiczynski in press) and co-verbal gesturing (Goldin-Meadow 2007). These might be considered different levels where pointing as a unit evolves, or they might altogether be considered different kinds of evolution because their evolutionary trajectories might be divergent instead of unilineal.

Pointing-behavior itself is also variable. Apes point with all fingers extended, while humans point canonically, with only the index-finger extended (Butterworth 2003). Scholars distinguish "imperative" pointing, from "declarative" pointing, and Tomasello (2000) argues that only the latter demonstrates the presence of theory of mind, which is refuted by Leavens et al. (2005). In conflicts like these, the heuristic advices to treat all different types as variations and to investigate these variations independently as different units, that possibly evolve at different levels, and that beyond LE, are possibly involved in different kinds of evolution.

(6, 7) Another query is whether the unit x is conjointly a level (*6*) or a mechanism (*7*) of LE. Especially when the unit is divisible into sub-units, and when the unit itself is thus a super-unit, the latter might be a level or locus where these sub-units evolve. Pointing, for example, might be a level where theory of mind evolves, because it serves as a vehicle where the trait can become environmentally expressed. Or, focusing on its particular sub-units, it can be the locus where index-finger extension becomes the target of a certain mechanism. And the genome, chromosome 7, the *FOXP2* gene, and the FOXP2 protein, for example, might (depending upon the hierarchy theory used) all be considered levels where the FOX region (the transcription factor) evolves. Such needs to be investigated from the level-heuristic onward (*6.a.*) and will depend upon the identification of specific units that evolve at these levels by specific mechanisms.

In so far as the transcription factor regulates gene expression, it might even be considered a mechanism of LE, but such needs to be studied independently from within the mechanism-heuristic (*7.a.*) and will depend upon finding and defining stable conditions whereby the gene induces change.

Here too, the same criteria define levels and mechanisms: if something is a level, it means that units can be identified as well as evolutionary mechanisms that are active upon those units, at those levels. Mechanisms are only mechanisms if they are active upon units at levels. If uncertain, the test begins from (respectively) level and mechanism onward. For a full discussion, see Gontier (2017).

5.2.5 The Evaluation-Phase

The yes-phase enabled you to identify x as a unit, and it has allowed you to *generate* and *constrain* specific research avenues. Now you may *evaluate* the obtained information and investigate what role this information plays in a unifying theory on LE.

(8) The final step to take when x is indeed a unit, is to investigate how relevant the unit x is or has been in LE by asking whether the unit is sufficient (*8.a.*) and/or necessary (*8.b.*) for language to evolve. These questions are not raised to investigate what is "essential" to LE. Rather, they serve to evaluate the importance of the unit and they enable to get an overview of the results that have been achieved by examining this unit. The questions also enable an assessement of the work that still needs to be done.

Suppose, for example, that there exist an all-encompassing Language Acquisition Device (-module/gene, Chomsky 1965) that is a unit of LE. Examining this LAD from within the above heuristic (as well as all its sub-units—if there are such sub-units) will, for the most part, have solved the problem of how language evolved. If, on the other hand, a gene or module for "Merge" is found, it will only explain recursion typical of universal grammar and mathematics. Or, if the human-specific shape and position of the tongue have been demonstrated to be units of LE, this will leave the researcher with the task of examining numerous other units, before he will solve the problem at hand.

If the unit x is sufficient for LE to occur (*8.a.1.*), it needs to be explained why there are other units involved (if there are). It seems likely that there does not exist such a single unit x, but this nonetheless needs to be proven. If it is insufficient (*8.a.2.*), it needs to be explained where it falls short in explaining LE.

If the unit x is necessary for LE (*8.b.1.*), x needs to be treated as a general (and perhaps even universal) unit of LE. This means that the unit x must have been present, at least during a specific period in time, during LE. And, important from an epistemological perspective, every theory that tries to explain LE needs to consider the evolution of this unit. If x is unnecessary for LE to occur (*8.b.2.*), neither of the two points are required. Rather, the unit may be regarded as peculiar to LE in general or as a particularity of a certain (aspect of) the evolution of (a specific) language/s, and it must thus not necessarily form part of a general theory on LE.

5.2.6 The No-Phase

(9) If x is not a unit of LE, you need to investigate whether x is either a mechanism or a level *of* LE, and if neither, whether it is a window *on* LE (*9.b.*). A window of LE is defined by Botha (2006: 132) as a phenomenon that is itself distinct from LE, but that nonetheless enables to draw inferences on the origin of language. Windows differ from the *actual* units, levels, and mechanisms of LE, but they provide insight into possible contexts of use of the units.

If the unit x is conjointly a level or a mechanism (*9.a.*), x needs to be treated accordingly, from within the heuristics presented in Table 4. When x is not a level, mechanism or window, x should be treated as irrelevant for LE until proven otherwise (*9.b.2.*).

6 Prospects

The above demonstrates how an applied evolutionary epistemological approach can help evolutionary linguistics. It formulates new research questions and it shows how we can examine existing data for new insights on LE. The application of AEE to as complex and heterogeneous a phenomenon as LE demonstrates how evolutionary epistemology itself can and must be extended into a methodology wherein not only multilevel selection is recognized, but where we come to terms with *unit, level, and mechanism pluralism*. Hence, we need to develop a hierarchical framework that allows us to search for the many different (super- and sub-)units, (super- and sub)levels, and (super- and sub-)mechanisms and we need to conceptualize their interaction.

It is clear that LE, as well as language itself is, at best, fuzzy, and no single unit, level or mechanism will do. The merits of the heuristics developed here is that they neither require intentional definitions of *what* language is nor functional definitions of *what* language evolved *for*. Both definitional types are rather central in current theorizing, with the Chomskian tradition focusing on the former and the Neodarwinian on the latter (see Gontier 2006 for a discussion). Here, these questions are circumvented. X is a unit if it evolves at a level by a certain mechanism; x is a level if certain units evolve at x because they are subjected to certain mechanisms; and x is a mechanism if it is active upon certain units at certain levels. Intensional definitions that explain the nature of units, levels and mechanisms can, at best, only be specified once all units, levels and mechanisms are identified. Then we can investigate what all have in common (if they indeed have something in common), and differentiate essential from accidental properties.

The epistemic questions central to this approach are *how, where, since when, how many*, etc. Not one of them makes it necessary to think teleological. Especially the issue of time and dating (the *since when* question) is highlighted in the heuristic. Evolution always occurs within a certain time frame for the whole concept of evolution implies that something comes into being that did not exist at a previous moment in time. Coming to terms with plurality necessitates investigations into the dynamics of when and how long and how many times units, levels, and mechanisms result in language, because there is no good reason to assume homogeneity and endurance or stability of all elements involved. This is especially the case when we surpass the genetic realm and move on to cultural levels. The heuristics will also deliver knowledge on *who* evolved language, and *where* this evolution occurred.

It is important to note that the heuristics are not merely devices that categorize the current data available on the units, levels, and mechanisms of LE. Rather, the heuristics are genuine investigative tools.

The heuristics furthermore systematize, generate, constrain, and allow you to evaluate the different research avenues. The search engines provide an answer to the question: when do we stop looking for new units/ when can we assume to have found all of them? The answer is that you can stop looking for new units:

1. When no new units can be identified that are subjected to evolutionary mechanisms at certain levels;
2. When the division or absorption of known units into sub- or super-units cannot identify new units of LE;
3. When all identified levels have been, after conclusive examination, included or excluded as units or mechanisms; and
4. When all identified evolutionary mechanisms have been, after conclusive examination, included or excluded as units or levels.

It is amazing how simple the different questions can be framed, and how difficult it is to provide an answer to every single one of them. It needs to be emphasized that every single question raised by the heuristic regarding a certain x that might be involved in LE, involves an individual research project. Nonetheless, all these different research routes can be brought together into one all-encompassing research plan. At the onset, the focus should lie at sub-units, sub-levels and sub-mechanisms and the more knowledge we have of these, the more we can build "the big picture" by investigating super-units, super-levels and super-mechanisms. This will naturally bring forth hierarchies and over time, consensus on the ontological layeredness might be reached.

The heuristics will only function properly when databases of the units, levels and mechanisms, and the hierarchies they form, are developed that are accessible for everyone (Gontier 2010a, b, 2012). AI and the internet could play a major role here. This might sound like a huge amount of work, but evolutionary biologists have for many years now, started to gather their data into genome and protein banks that are freely accessible for everyone. Scholars are more and more able to process large datasets, not in the least because of progress made within bioinformatics approaches. In this regard, a recent initiative should be mentioned called D-Place (Kirby et al. 2016). This is a databank that aims to link cultural information to language phylogenies and to geographic locations and environmental features. Such a database could also function to identify and store the units, levels and mechanisms of LE.

When natural history scholars just started the investigation into the origin and evolution of language, they first and foremost focused on theory formation, and a race began over which theory was more plausible than another, but most ended up as just-so stories. Today, due to the large datasets available to us, we have come to realize that one person cannot develop one all-encompassing theory, and scientists are more willing and able to collaborate. Identifying units, levels, and mechanisms of evolution will depend upon consensus views formulated by the community, and it will be a challenge to get things organized accordingly.

Once the heuristics should start to get implemented, it might be possible to also develop smaller heuristics that can function as search engines that point out recurring patterns or perhaps even "universals". Such universals might include clusters, that demonstrate that certain units always co-evolve, and a specific unit might not evolve in the presence of another (speech versus gesture, for example). A certain unit can perhaps always evolve when it is subjected to mechanisms x, y and z, regardless of the level/s. Or a certain group of mechanisms might always work together in (an aspect of) LE. Such are possibilities, that will highly likely be made clairvoyant when the heuristics become implemented.

Scientists are doers, while this work is written from a philosophical and thus theoretical perspective, and my aim is to focus on the underlying epistemology that grounds and justifies the steps taken along the way.

Finally, it needs to be noted that the heuristics do not mimic how language evolved. Thus, it is not because the heuristics are algorithms that I assume that language evolved algorithmically. Rather, these algorithms are argued to be a "how to study LE", they provide a manner whereby we can break into the evolutionary events.

This approach is characterized by first dividing the research subject into parts; subsequently studying the parts independently, thirdly studying the relation between the parts; and fourthly, by justifying, confirming and by trying to falsify every single step along the way. This does not imply that I assume that the sum total of the parts equals the whole because fifthly, we should also investigate how the combination of parts results in characteristics that are irreducible to those parts. Most evolutionary processes are characterized by such emerging events.

Whether the heuristics will actually provide all the relevant data on how language evolved (how the units, levels and mechanisms evolved, interact, etc.), and thus whether it will enable us to build one single all-encompassing theory on LE, is a question that I cannot answer at present. I am convinced, though, that it will take us a long way down the road.

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