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An anthropic principle in lieu of a "Universal Grammar"

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Abstract

Among the many unanswered questions in grammar theory, the following figure prominently. *First*, what is it that enables children to successfully cope with the structural complexities of their mother tongue while professional grammarians tend to fail when modelling them? An innateness conjecture would merely beg the question. There is no compelling evidence for specific properties of linguistic expressions to be innate, that is, genetically coded somehow.

Second, what determines the narrow system corridor for human grammars? On the one hand, no two human languages share an identical rule system, but on the other hand, grammars demonstrably do *not* differ from each other "without limit and in unpredictable ways".

Third, are the grammars of human languages the offspring of a single proto-grammar instantiating a "Universal Grammar" (monogenic) or are the shared traits of human grammars the result of *convergent changes* in the grammars of human languages of diverse ancestry (polygenic)?

An analogue of the cosmological Anthropic Principle in combination with the Darwinian theory of evolution applied to replicative cognitive programmes helps clarifying these issues. There is no urge for assuming a "Universal Grammar", but nevertheless, languages share fundamental grammatical properties as a result of the predictable *convergent* cognitive evolution of their grammars.

1. Anthropic grammar theory

The Anthropic Principle[1] in cosmology states that by our very existence as carbon-based creatures, we impose a sort of selection effect on a habitable universe. If, for example, just one of the numerous fundamental constants of nature were slightly changed – e.g. the strength of gravity – our life form would not be possible and no human brain could wonder why natural constants have precisely the values they have. The cosmological universe could be entirely different and human beings would not be part of it.

The Anthropic Principle turns the original question – *How come that the fundamental constants in the Universe have precisely the size they have, although their sizes could be different*? – upside down: Since we could not exist in a universe with different fundamental constants, we must not be surprised by the fact that the universe presents us exactly the constants that are necessary for the existence of biological life forms we are familiar with.

The analogue[2] epistemological issue in grammar theory is the question why grammars of natural languages occupy only a small region within the system space of discrete symbol manipulating systems, namely a sub-region of "mildly context-sensitive" languages (see Joshi 1985, Shieber 1985). The universe of grammars for an intelligent species could be entirely different, except that human language grammars arguably would not be part of it because our human processing resources would be either unable to put them to use efficiently or would persistently

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[1] Anthropic Principle (weak): The observed values of physical and cosmological quantities are not equally probable but they take on the values restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirement that the Universe be old enough for it to have already done so. (Barrow and Tipler 1986:16).

[2] I am very grateful to *Harald Uhlig* (Department of Economics, University of Chicago), who made me aware of the instructive parallel between the *Anthropic Principle* and what I had tried to outline him as an evolutionary alternative to an innateness-based UG (= universal grammar) conjecture (Bonn, June 26, 2018).

invite changes towards exploiting the available system potential more effectively. The grammar systems may make the most of the neural processing capacities of brains, but they cannot go beyond them.

Grammars and production systems below or above the threshold of "context-sensitive" are known from many other fields, ranging from formal language theory to symbolic logic and complexity theory, but not from languages 'out of the wild'. Intriguingly, many if not all natural languages employ the computational power of context-sensitive languages[3] although, for human communicative purposes, computationally much less powerful systems would suffice. Even if human languages were "regular languages", which can be processed by a finite-state automaton [Partee, Ter Meulen & Wall (1990), ch.17)], the communicative functions could be met as well as with our present day languages. Neither poets nor journalists, neither lawmakers nor scientists would feel notably impeded, not knowing that computationally more powerful tools would be possible. The major difference would be one in grammar theory but not in the aptness of such a language for social communication.

Human language grammars are but tiny islands in a sea of context-sensitive grammars which in turn is part of an unbounded ocean. Why do other types of grammars apparently not exist in the realm of *human* languages? The cognitive analogue of the Anthropic Principle suggests a specific answering strategy, namely the 'anthropic' one. Natural languages have the properties they have because they reflect the properties which our language-learning and language-using human brain capacities can cope with. Systems beyond this capacity are thereby excluded. A grammar that is not effectively learnable will never become a grammar in use. On the other hand, grammars may develop into luxurious systems when adapting to the system potential of human brains within its boundaries. For instance, morpho-syntactically much simpler systems would suffice for the communicative (and also for the cognitive) functions of language, as Chinese exemplifies.

The human language processing resources are recruited resources whose history of evolution is non-verbal. Language processing is parasitic on available resources. Therefore, with respect to language processing, their properties are contingent on a non-linguistic selection background. Hence, from the standpoint of grammar theory, their reflection in the architecture of human grammars are reflections of an accidental ensemble. This, viz. the accidental quality of grammar constants, is parallel to the apparently accidental quality of nature constants.

The original non-anthropic and in fact stipulative answer to the first question by Chomsky (1975) – Humans happen to be equipped with an innate "universal grammar" – has been highly improbable from the beginning. The inappropriateness of innateness claims has been re-emphasized from a philosophy of science perspective (Lin 2017), language acquisition research (Braine 1994), as well as from neighbouring fields (Dąbrowska 2015). It is merely begging the question as long as there is no compelling evidence for parallels between the human language capacity and innate information processing capacities of other species in terms of their hereditary and genetic properties.[4] Findings from studies of the apis mellifera (honey bee) dance lan-

[3] The type of automaton required for its computation is at least a "linear bounded automaton" (LBA), that is, a subset of Turing Machines with specific storage limitations for the input; see Partee, Ter Meulen and Wall (1990), chapter 20: "Linear bounded automata, context sensitive languages and type 1 grammars."

[4] If a formally rich system such as the structures of a grammar of a human language were genetically determined in detail, genetic defects should affect circumscribable subparts analogous to brain lesions that knock out narrowly circumscribable language functions. The only evidence we have is that the Forkhead-Box-P2 gene, situated on the

guage show that even 'dialects' (in linguistic terminology: cross-linguistic differences in grammar) are *genetically* differentiated (Johnson et al. 2002). So, it would be far from outrageous to insist on a genetic basis of differences between, let us say, indigenous users of PIE languages in comparison to indigenous users of topic-prominent East Asian languages, with a highly impoverished morphological system. No grammarian has ever published such results in the *Journal of Heredity*, and pertinent findings in human genetics are discouraging, as one would expect anyway.

According to Chomsky's original UG conjecture, human brains are *endowed* with a singular capacity for acquisition, implementation and use of highly specific rule systems of grammars. As it is a singularity, its properties must be taken for granted as a serendipitous quality of human brains. However, a singular capacity could in principle have any other computational organization. Moreover, it is highly unlikely if not impossible that such a singularity, that is, an extremely complex innate disposition, could fulgurate in a single species. The evolution of a complex innate capacities would proceed step by step and would show in other species as well.

The idea that humans are endowed with a richly structured, innate language capacity has served as a tentative solution for the *argument from the poverty of stimulus* in language acquisition, that is, the insight that the grammatical competence attained by a child in first language acquisition is underdetermined by the linguistic intake if learning were a matter of trial & error. Children easily master two problems that linguists struggle with, namely, on the one hand, evidence from the absence of evidence. Is a given structure missing because it is excluded by the system or is it accidentally missing? On the other hand, children arrive at a complete grammar on the basis of variable and partially indeterminate input. Trial-and-error learning and learning by generalizing patterns could not account for the perfection of the acquisition process.

In general, and in linguistics in particular, the initial *absence* of evidence for a certain property cannot be regarded as evidence for the absence of this property. Here is an illustration from English.

How could a monolingual child acquiring English arrive at the categorical insight that a particular class of structures is ill-formed without insourcing negative evidence in the form of trials and corrective feedback? Children do not and could not test out rare syntactic variants. Nobody has ever observed a child checking out multiple wh-question patterns. Nevertheless, speakers of English uniformly end up with a steadfast refutation of *'how'* or *'why'* in (1a), in place of 'therefore' or 'strongly' in (1b), even if they have never heard or uttered this particular pattern of multiple wh-questions question before

German speakers, on the other hand, would not find fault with the semantically and syntactically corresponding items 'weshalb' (why) and *'wie'* (how), as in (1c).[5] Crucially, this is not a peculiarity of English versus German. It is a cross-linguistically valid phenomenon. English is representative of languages with strictly head-initial verb phrases and a subject position outside of the VP, a.k.a. 'SVO' languages. In other words, the restriction behind the pattern (1a) is a

long arm of chromosome 7, seems to play a role in inherited SLI. However, this gene has been found to be crucial also in songbird brains (Teramitsu et als. 2004). Mutations may result in disorders of learning or using a given grammar, both in human and avian brains. But birds don't use a human language grammar, so FOXP2, of course, cannot be regarded as the 'grammar gene' of homo sapiens.

[5] (i) *"Wer* hat *weshalb* begonnen, und *wer* reagierte *wie* auf die der Gegenseite unterstellte Provokation?"
who has *why* begun, and *who* reacted *how* on the alleged provocation of the opposition
Frankfurter Rundschau-25.07.2017. http://www.fr.de/politik/meinung/gastbeitraege/g20-krawalle-woher-kommt-die-gewalt-a-1319313 (accessed June 30, 2018).

property of genuine SVO languages. This restriction is neither found in SOV languages nor in languages with variable head-positioning, such as the Slavic languages; [see Haider (2018a), (2018c), Haider & Szucsich (2018)].

(1) a.* Who has *why/how* objected? – *It is unclear who has *why/how* objected.
b. (that) they *therefore strongly* objected
c. Wer hat *weshalb/wie* protestiert? – Es ist unklar, wer *weshalb/wie* protestierte.
who has why/how objected – it is unclear who *why/how* objected
d.* *Who* objected *why/how?* – **Why/How* did *who* object?

There are even cases of unavoidable clashes, as for instance (1d). Since wh-fronting in an SVO-type language must neither leave behind an interrogative subject nor a semantically higher-order wh-quantifier such as 'how' or 'why', and since there is only a single wh-slot open for fronting, there is no well-formed ordering for (1d) available (Haider 2013:138-142; Haider 2018a,b). German, Japanese or Russian,[6] to name just three non-SVO languages, are not subject to such a constraint.

The grammatical source of the restriction underlying (1a) is epiphenomenal. It is implicated by a general restriction on head-initial phrases to be explicated below. Children are not misled by the fact that normally, in multiple questions, the second occurrence of an interrogative phrase is left in-situ, that is, in the exact position in which the non-interrogative phrase would occur. This would be the position of *'therefore' and 'strongly'* in (1b). Hence, an obvious question is this. What prevents an English child from entering the German-Japanese-Russian route? The answer is identical with the answer to the question as to how such constraints have come into being in SVO languages, as will be argued below.

Chomsky (1975) contemplated this kind of decision problems for a learner, but his original solution – an innate language acquisition device resting on an innately preconfigured grammar that excludes constellations as in (1a,d) – has remained unfounded. Nobody has ever been able to produce immediate and compelling evidence in favour of the strong nativist hypothesis. It is a bold conjecture that has not worked out. Even its proponent (Chomsky 2001) prefers to get rid of it.[7] The original question was this. What enables children, given their feeble cognitive capacities, to acquire a complex and intricately structured system of symbol manipulation?

Here is the 'anthropic' answer: Grammars that children could not fully grasp would not come into existence, simply because no human brain would acquire and then use them. So, what makes a grammar learnable? The 'universal constants' of the universe of human grammars are constants that characterize learnable grammars for human brains. Our grammar systems are the result of a process of cognitive evolution in which the human language processing resources are the selection environment. Languages are learnable since the grammars of human languages have been selected for learnability by the numerous generations of grammar acquiring brains and there is an enormous amount of grammar variants that did not pass the selection filters, but we do not know them.

[6] In typological surveys, Slavic languages tend to be misclassified as SVO, simply because the linear order of subject-verb-object happens to be a frequent pattern in simple clauses in each of these languages. However, when a sufficiently large set of characteristic SVO properties is systematically scrutinized, it turns out that Slavic languages are not SVO. They are languages with *variable head positioning* (Haider & Szucsich 2018).

[7] [...] "the best answer would be that a sudden and very slight evolutionary event yielded Merge, and that the rest follows from natural law". (Chomsky 2011:275).

Such an answer must be framed in terms of the insights we owe to Charles Darwin. Complex systems do not suddenly appear from nowhere. They are the result of evolutionary processes that apply to human 'software' packages or 'apps' for languages, a.k.a. grammars of natural languages. These cognitive systems are subject to the very same principles of evolution that determine genetic evolution: variation + selection = adaptation.

2. The inevitable cognitive evolution of grammars

No zoologist ever had to insist on a "universal grammar" of sea-dwelling life, for instance. This does not contradict the fact that many species have independently developed fins, fin-like extremities or webbed feet. We may call them values of anatomical sea-life "parameters". Even when mammals re-entered the sea, they developed into orcas, dolphins or seals, to name just a few species, and they developed fin-like arms and legs. In other words, there is no need for a universal grammar of sea-dwelling and surely not for an innate one in order to be able to explain why there are invariants across organisms in the same habitat. The theory of evolution is sufficient. Languages share a habitat, namely the same neuro-cognitive environment for acquisition and use. A language with grammar G can survive only if G happens to enter enough brains and this is why cognitive evolution leads to neuro-cognitive adaptation of grammars to brains.

Darwinian evolution is not substance-bound, that is, it is not restricted to the genome of biological systems. Evolution inevitably takes place whenever a *self-reproducing* system is open for *variation* and is embedded in a context that constantly *sieves out* variants. On the level of cognitive structures, grammars are self-reproductive in the same way as a virus[8] is self-reproductive on the level of cellular structures (Haider 2015).

In the long run, only those variants will survive that are not sieved out. In other words, variants win that happen to turn out as 'fitter' within their selecting environment. Fitness of a grammar means that more learners ingest and implement this particular grammar than other, slightly different grammars. The emergent result is a neuro-cognitively better-adapted grammar system.

Adaptation to an environment is a consequence of *random* variation of self-reproducing systems exposed to an environment with *constant* selection. The neuro-cognitive apparatus is the constant selector for grammars. Communicative utilities of a language cannot function as selectors in evolution since they are changing. When functional grammarians invoke the concept of evolution (Croft 2013), they use it metaphorically or misapply it (Haider 2015), since they focus on communicative functions, but evolution cannot be aimed at moving targets. Grammars are cognitive information structures. They are neuro-cognitive 'software' packages, or in present day jargon, "apps" for language processing. Grammars manage the processing of *structures* rather than the handling of communicative *functions*.

A Grammar is – even literally – a cognitive virus programme. It reproduces itself, but it needs a host that provides a replication environment, just as any virus does. Grammars 'infect' human brains as a result of language acquisition. The cognitive virus corresponding to the grammar of our mother tongue governs our language production behaviour. Language usage is the reproduction device for the virus. Children acquire their grammar on the basis of being exposed to language productions and they put it to use. Afterwards, their productions become part of the input for the next generation's acquisition of grammar, and so on.

[8] According to Koonin (2012:294), a virus is encoding information required for its reproduction and, hence, it possesses a degree of autonomy from the host (genetic) system. Grammar encodes the information for language production and reception by the host organism, viz. language users. This is necessary for reproduction of the 'virus' in language acquisition. A virus may be coded genetically or purely informationally (cf. computer virus).

Such a reproduction process is perfectly imperfect. An inevitable by-product of inaccurate acquisition is variation. Variation – as in the case of mutations in the biological instantiation of evolution – is enhanced by various other factors, including language contact or dialectal segregation. What this scenario amounts to is an instance of Darwinian evolution on the level of cognitive structures and their variants. Researchers interested in the "evolution of language" traditionally focus on the *biological* features on the one hand and speculate about their *communicative* use on the other hand.[9] As a consequence, too little is known about the true ground zero of the evolution of grammars, namely the evolution of cognition in general and in particular the evolution of language processing capacities as a central part of our cognitive inventory.

Evolution inexorably results in adaptation to the selecting environment.[10] The selecting environment for grammars is the ensemble of cognitive capacities of our brains that has gotten recruited for language processing. Their history of evolution is independent of language. In the evolution of humans, complex grammars of languages are too recent an achievement to be a result of *biological* selection on its own.[11] Grammars adapt to the brain. "*Overall, language appears to have adapted to the human brain more so than the reverse*." (Schoenemann 2012: 443).

Language processing has always been parasitic on already existing computation capacities of the human brain which have existed already before these brains started with language (Christiansen et als. 2009). This set of capacities is a selector for an ongoing adaptation of grammars to the neuro-cognitive processing environment. Grammar variants that can be more easily acquired or more efficiently used, will eventually 'infect' more brains than other variants in the long run. As a consequence, grammars will become locally optimized for learnability and online usability. Present day grammars are a product of cognitive evolution rather than a perplexing instantiation of a mysterious "UG".

Here is an example of the recruiting of already available brain resources for language processing. Broca's and Wernicke's area in the language-dominant hemisphere are hotspots in the cortical language processing circuits. But they are no homo-sapiens innovation.

"*Our findings support the conclusion that leftward asymmetry of Wernicke's area originated prior to the appearance of modern human language and before our divergence from the last common ancestor.* (Spocter et als. 2010: 2165). "*Broca's and Wernicke's areas, and the arcuate fasciculus connecting them, were not specially evolved for language*" (Schoenemann 2012:455).[12]

Let us return to the initial example. How can a child find out that (1a) is ill-formed, given that it notices that (1b) and (2a) are in use? It cannot and it need not. It is the processing system that shies away from the kind of structure that (1a) would instantiate in a language with head-initial

[9] "*A look at the literature on evolution of language reveals that most of it scarcely even addresses the topic. Instead, it largely offers speculations about the evolution of communication, a very different matter*." (Chomsky 2011:265.)

[10] This is a corollary of Fisher's theorem. "*Assuming that natural selection drives all evolution, the mean fitness of a population cannot decrease during evolution* (*if the population is to survive*)." (Koonin: 2012:8).

[11] In comparison to songbirds (Brenowitz 2008), our brains are not a priori 'hardwired' for language processing. Each of the brain functions and brain regions recruited for language processing supports other functions, too, and moreover, they are already functioning in the brains of our nearest relatives, as for instance bonobos, who do not use complex grammars.

[12] "*Functional asymmetries in the brain were initially thought to be uniquely human, reflecting unique processing demands required to produce and comprehend language. Nonetheless, functional and structural asymmetries have been identified in nonhuman primates and many other species."* (Toga et als. 2010: 99).

phrases. (1a) requires the very same structure that would be needed for (2b). Needless to re-emphasize that the counterparts of (2b,c) are fully acceptable in non-SVO languages (2d,e).

(2) a. *Why* did they object? – *How* did they object?
b.*They have *more than twice/with great emphasis* objected[13]
c. It has *more recently* (*than we thought) gained popularity.
d. Sie haben [viel öfter als wir] [mit großem Nachdruck] widersprochen. German
they have [much more-often than us] [with great emphasis] objected
e. Es hat sehr viel früher (als wir dachten) Popularität erlangt.
It has very much-*more recently* (than we thought) popularity gained

(1a) is ruled out by the very same grammatical restriction that rules out (2b) or the bracketed extension in (2c). It is a restriction on left adjuncts of left-headed phrases (Haider 2018b). The acceptable versions, such as (2c), are phrases with an adjacent, semantically selecting head. Wh-items are non-selecting. They count as phrasal. Therefore, they are disqualified as pre-adjoined adjuncts of head-initial phrases.[14]

In head-final phrases, these items are within the directionality domain of the verb, whence the absence of the particular constraint in German. The overarching constraint is a directionality requirement of 'gluing' non-selected phrases to licensing heads. Left-hand adjuncts of head-initial phrases are outside of the licensing domain of the head of the host phrase, hence they must be 'glued' to the phrase, which amounts to a head-adjacency requirement (Haider 2018b).

3. Convergent evolution of grammars under cognitive selection

Haeckel's biogenetic law of 1866 – *Ontogeny recapitulates phylogeny* – is a good starting point, even if it has been discredited in many details. Von Bear (1928) formulated a more accurate insight, claiming that the general characters of a taxonomic group show earlier in an embryo than the specialized characters do. Species diverge from one another as development progresses. He concluded that the stages an embryo passes through during ontogeny never represent *adult* forms of other species; they only represent *embryonic stages* of other species.

As for the evolution of grammars, the analogous situation is the following: The acquisition paths in first language acquisition recapitulate steps in the evolution of grammars in the history of mankind. Von Bear's linguistic version would be this: In early stages of language acquisition – until leaving the two and three-word stage – children proceed independently of the patterns of their respective mother tongues. For instance, children may choose V-subject orders even in languages in which the subject would invariable precede the main verb (Deprez & Pierce 1994:64-65). Their behaviour arguable resembles the "*embryonic stages"* of human languages in the evolutionary history.

Another window into the 'embryonic phase' is the isolated emergence of new languages, as in the case of a Nicaraguan sign language (Senghas et als., 2004) or in experimental tasks (Goldin-Meadow et al., 2008). In each of these cases, an SOV word order is preferred for denoting transitive events. When children enter grammar acquisition, they proceed from a "*Me Tarzan"* and *"You Jane" kind of stage* to end up after a couple of years in a steady state that governs

[13] The *British National Corpus* (BNC) of 100 million words contains 166 tokens of "has therefore", but not a single token of "has why" or "has more often than x" (with x as the target of comparison), although "has * often" (* as a word joker) is attested 64 times. The respective numbers for CocA (520 million) are: 113 – 0 – 0 – 111.

[14] This is confirmed by left-hand attributes of head-initial NPs in comparison to left adjuncts of a head-final VP:
i. ein [viel schlechteres (*als dieses)] Argument$_{N°}$ ii. Er hat [viel besser (als alle anderen)] argumentiert$_{V°}$
a much worse (than this) argument he has [much better (than all others)] argumented

complex utterances such as "*Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous fortune, or to take arms against a sea of troubles, and by opposing end them.*"

It is an educated guess that our human ancestors, just like today's children, have started with two and three word utterances, with little to no restrictions that would deserve the denomination 'grammar'. From then on, cognitive selection has been working steadily and unavoidably and it rewarded and conserved variants that turned out to ease processing or learning. Of course, this precesses of selection were dependent on the existence of variation on the one hand and on the other hand, selection is non-deterministic. Just as in biological evolution, it is unpredictable which specific step will happen and when, and evolution may even lead into dead end regions. Some linguistic 'coelacanths', such as the Salish languages (Jelinek & Demers 1994), have remained in a very early design. In these languages, lexical categories apparently do not exist. The arguments of a lexical item are merely differentiated by morphological markers, not by lexical category or phrase structure. These markers serve as identifiers for the arguments in the argument-predicate relation. Lexical categorization is a precondition on the way of arriving at phrase structuring, with phrases differentiated by the head categories.

Only much later and only in a subgroup of languages, the *morphological* coding (3a) of grammatical relations got replaced by an even more efficient *structural* coding in terms of head-initial and thus strictly linearized phrase structures (3b) that allow for an efficient *procedural* identification of essential relations. (3b), for instance, contains four times more prepositions than (3a). No language is known that has gone the reverse way, that is, starting with an English or Chinese grammar and ending up with a Sanskrit grammar.

(3) a. Gallia est omnis divisa in partes tres, quarum unam incolunt Belgae, aliam Aquitani, tertiam qui ipsorum lingua Celtae, nostra Galli appellantur. (Latin; Caesar, De bello Gallico)
b. All Gaul is divided into three parts, one of which the Belgae inhabit, the Aquitani another, those who in their own language are called Celts, in our Gauls, the third.

Given the scarcely populated African and Eurasian continent during and after the "Me Tarzan – You Jane" millennia, polygenesis of grammars is much more probable than monogenesis. The cross-linguistic invariants of modern languages are the reflex of convergent cognitive evolution (Pearce 2011) by constant selection of grammar variants by the invariant neuro-cognitive processing resources that constitute the human language-processing facility.

At the end, there has emerged an apparently domain specific language capacity. But this impression is merely a tunnel-view perspective on the problem. The specific ensemble of brain resources recruited for language processing may appear to be domain specific. However, its components are not domain-specific at all. They have been recruited from the already existing and therefore available cognitive processing resources of the primate brain. If viewed from this angle, there is no need for an innateness conjecture.

As a simple illustration of this idea, consider for instance your laptop. It is a domain-general device. One may type papers, send e-mails, watch videos, listen to music, calculate statistics, and so on. A text editor is a specific combination of available computation resources of the laptop that amounts to a domain-specific application. The resources it combines are domain general, the specific combination of the resources amounts to a domain specific application. Grammars are cognitive apps for language usage. These apps have been shaped by cognitive evolution. Biological evolution has shaped brains that happen to provide the computational capacities for 'running' such cognitive apps.

Human acoustic decoding, for instance, capitalizes on categorial perception. This capacity of our brain is not species-specific. Chinchillas, monkeys, chicken or rats dispose of it (Kriengwatana et. als. 2015). However, as it is an available and useful resource of human brains, too, it got recruited for language processing. The whole ensemble of human computation resources is the selecting background environment for the evolution of grammars. A grammar variant has a chance to occupy more brains if it is better adapted, that is, if it is rewarded by brains that reward structures that can be processed more easily and effectively.

Due to the lack of script in most languages, the historical depth of documented grammar changes is shallow. Nevertheless, what we know is sufficient for realizing clear effects of ongoing evolution by variation & selection. For instance, Fisher (1930) formulated and proved a fundamental theorem of natural selection, commonly known as *Fisher's theorem*: "*The rate of increase in fitness of any organism at any time is equal to its genetic variance in fitness at that time*." In other words (Koonin 2012:7), the *intensity of selection* and hence, the *rate of evolution* due to selection, is proportional to the magnitude of variation in an evolving population, which, in turn, is *proportional to the effective population size*. This accounts for the fact that Icelandic and Faroese are much more conservative than Swedish or Danish, and that English has been vastly more prone to change than Scottish Gaelic, for example.

The *Hardy-Weinberg equilibrium* of population genetics, on the other hand, states that within sufficiently large populations, the allele frequencies remain constant from one generation to the next unless the equilibrium is disturbed by *migration* or *selection*. The same is true for languages. Grammar change takes place in small subpopulations before it may get a chance to spread. In large populations, continuous contacts would level out the variants of subpopulations.

Summary: Darwinian evolution working on the *cognitive representations* of linguistic structures processed by the human brain provides adequate answers to the three initial questions: Grammars are learnable since learnability is the prime factor of the selecting cognitive environment. Better learnable variants will occupy more brains and spread.

Second, human languages stay within a corridor delimited by originally non-verbal brain resources recruited for actual grammar usage. Third, there is no need for insisting on a monogenetic origin of human grammars. Cognitive evolution fully accounts for the cross-linguistically convergent as well as divergent traits of human grammars.

Finally, 'universal grammar' is a readily disposable hypothesis. A theory of cognitive evolution provides a more rewarding approach. What is innate is not the grammar format. The brain capacities recruited for language processing are innate and these are the selectors in the permanent cognitive evolution of grammar.

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