Language evolution and complexity considerations:
The *no half*-MERGE *fallacy*

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Abstract

Recently, prominent theoretical linguists have argued for an explicit evolutionary scenario for language on the basis of computational properties of the language faculty. Specifically, the simplicity of a minimal(ist) formulation of the operation MERGE, which allows humans to recursively compute hierarchical relations in language, has been used to promote a sudden emergence, single-mutant scenario. A major argument for this view is that MERGE is either fully present or fully absent: one cannot have half-MERGE. From there, proponents of this view conclude that the emergence of the Merge phenotype had to be sudden, drawing a parallelism between the formal complexity of the operation at the computational level and the number of evolutionary steps it must imply. Here we examine this argument, and show that it rests on tenets that do not hold, and therefore cannot be used as justification for a single-mutant theory of language evolution.

1 Introduction

The capacity for language is a defining trait of the human species. Understanding the nature of this capacity and how it came to be is a major topic of research. A leading proposal on the nature of the capacity, coming from the work of Chomsky (e.g. Chomsky, 1965) and colleagues, is that humans are equipped with some form of innate circuitry that allows for recursive computation over hierarchical structures. The theory describing this capacity has changed over the decades, with the most recent major articulation (Chomsky, 1995) proposing a basic operation, named MERGE. In its minimal expression this operation takes two linguistic units α and β, and form a set $\{\alpha, \beta\}$, which can in turn function

1

as a unit to be further combined: $\{\ldots\{\gamma,\{\alpha,\beta\}\}\ldots\}$. MERGE is claimed to be enough to yield grammatical structure and unique to humans. As for the question of evolution, in a recent book, Berwick and Chomsky (2016) propose that MERGE, being such a simple operation had to be the result of a single genetic mutation that endowed one individual with the necessary biological equipment for language, rendering MERGE the result of what would be in effect a macromutation.

There are different parts to the position of Berwick and Chomsky (2016), to which we will return below. But the key argument that interests us here is the claim that MERGE is either fully present or fully absent as justification for its sudden, single-mutation emergence.

Their argument goes as follows: since there can be no intermediate steps between "not having MERGE" and "having MERGE" as a formal operation underlying recursion—in other words, there cannot be such a thing as half-MERGE—, there can be no multiple, gradual evolutionary steps accounting for its emergence. Thus, MERGE, and with it a full-blown modern language faculty, must have been the result of a sudden, single mutation. We will call this the "no half-MERGE" argument.

In what follows, we will analyze this argument, and show that it rests on tenets that do not hold ("*no half-*MERGE *fallacy*"). We will conclude that it cannot be used as justification for a single-mutant theory of MERGE, nor of human language, and that a different view is warranted.

2   The no half-MERGE argument

The single-mutant theory of language evolution in Berwick and Chomsky (2016) rests on a number of points that are presented as tightly connected. In a nutshell: there was a Great Leap Forward, an unprecedented explosion of symbolic capacity and production sometime between the appearance of anatomically modern humans and a single exodus from Africa; roughly 100,000 years ago (Berwick and Chomsky, 2016). This can only be explained by a sudden (and single) genetic change that endowed one or a very small number of individuals with very advantageous capacities, reflected in its clearest expression in language. The actual result of that change was the operation MERGE. This operation is said to be optimal and undecomposable. Furthermore, Berwick and Chomsky (2016) state that things could not have happened otherwise, since there was not enough time for a more complex evolutionary scenario, comprising multiple steps, to happen in a short time span. It is vital for this proposal that each of these aspects be the case, for they rest on one another.

Even though the present paper focuses on the atomicity of MERGE and its evolutionary implications, we see evidence for doubting the other strands of the Berwick-Chomsky argument. The Great Leap Forward, single-group exodus out of Africa story, taken for granted in Berwick and Chomsky (2016) is losing its original appeal, with mounting evidence in favor of a multi-group, multi-step evolutionary scenario for *Homo Sapiens* (Mcbrearty and Brooks, 2000;

Stringer, 2016; Scerri et al., 2018). The argument that there was not enough time for multiple mutations to arise has recently been modelled, using all the parameters and assumptions from Berwick and Chomsky (2016), and, contrary to expectations, a multi-step scenario turns out to be much more plausible (de Boer et al., 2019). These are thus independent reasons for doubting key aspects of the single-mutant theory of the evolution of language.

Let us then turn to the third aspect of the proposal of Berwick and Chomsky (2016), namely that the result of the change — the MERGE operation—, is atomic, meaning that in any case it couldn't have evolved by means other than sudden emergence caused by single mutation, for this "phenotype" does not allow for intermediate steps. Berwick and Chomsky (2016) put it as follows:

> "...a plausible speculation is that some small rewiring of the brain provided the core element of the Basic Property: an optimal computational procedure, which yields an infinite array of hierarchically structured expressions, each interpreted systematically at the conceptual interface with other cognitive systems. [...] It is, in fact, not easy to conceive of a different possibility, since there can be no series of small steps that leads to infinite yield."

The argument has been stated most succinctly (and endorsed) by Dawkins (2015): "There's no such thing as half-recursion. It's an all or nothing software trick." (Dawkins, 2015, p. 290); "[...] it's not totally implausible that such a faculty might have come about in a single mutation, which we should probably call a macro-mutation." (Dawkins, 2015, p. 382)

We now turn to different aspects of this argument, and point out why it can't be used to justify a single-mutant theory of language evolution.

3 The *no half-*MERGE *fallacy*

Berwick and Chomsky (2016) define the language phenotype as equivalent to MERGE. This aids their position in other work (e.g. Bolhuis et al., 2014) where they downplay any possibility of gradual emergence of language. This is of course not an innocent assumption: that the language phenotype can be equated directly with this special recursive operation. This is perhaps the length one has to go to in order to defend a single-mutant theory of language (reduce the phenotype to something mathematically very simple). This reduces all possible theories of the evolution of language to those who relate to MERGE, all others categorically excluded, since according to the authors they are not theories about the same thing, the language phenotype as they define it. One other problem that arises concerns the actual change that supposedly took place: the authors never entertained what that change might be. An unnamed mutation stemming from this reductionist definition of the language phenotype does not allow for meaningful research on the topic of language evolution. This is particularly unproductive, now that we are getting to the point where we have the tools to look at all the changes between Modern Humans and Neanderthals that

reached fixation (Pääbo, 2014). Under Berwick and Chomsky's assumption that Neanderthals didn't have language, the mutation giving rise to MERGE, if it in fact occurred, would be among these fixed changes.

Theories of language competence rest mainly on formalization. Under the assumption that the system we are interested in is a biological one, formalizing a linguistic mechanism is equivalent to describing it at the computational level in the Marrian sense (Marr, 1982). There are some recent comments on the challenges this brings about when facing the issue of language evolution (e.g. Johnson, 2017; Perfors, 2017). The computational level describes *what* is being done. The other two levels are the algorithmic (*how* something is being done) and the implementational level (the *physical implementation* in the brain, and all the way down to the genome). When Berwick and Chomsky (2016) and colleagues defend the single-mutant emergence of language because it is not possible to have half-MERGE or half-recursion, they can only be referring to the computational level—that's the level at which MERGE is. Yet they extrapolate to the other two levels, which are very different in their ontology and in their complexity.

MERGE, in its simplest formulation, is an operation which takes α and β and forms the set $\{\alpha, \beta\}$, the idea being that the structural properties of language fall out from it. But its simplicity is only apparent. For MERGE to adequately capture the core structural traits of linguistic competence, it must be formulated in such a way as to capture the distinction known to linguists as "external MERGE" (forming nested dependencies) and "internal MERGE" (forming crossing dependencies), e.g.: $A^n B^n$ vs. $A^n C^m B^n D^m$. Chomsky (2004) has stated that the most natural version of MERGE should include both external and internal MERGE options, as it would take an extra assumption to ban crossing dependencies: it would take an extra assumption to prevent Merge from re-merging an already merged element. However, this is not necessarily so (Uriagereka, 2008). If we go back to the Chomsky hierarchy (Chomsky, 1956) (Table 1), which we still take to be a useful categorization of the kinds of grammars that are computable, crossing dependencies were argued to require a level of complexity (mildly context-sensitive) over and above that required for nested dependencies (context-free). That is to say, crossing dependencies require more computational memory resources. Accordingly, they cannot simply be assumed to be part of the default Merge definition. Thus, it is perfectly reasonable to entertain

Class	Grammar	Automaton
Type-3	Regular	Finite-state
Type-2	Context-free	Push-down
Type-1	Context-sensitive	Linear bounded
Type-0	Unrestricted	Turing Machine

Table 1: The Chomsky hierarchy and corresponding automata

a multi-step scenario for MERGE, with at least two steps: one step taking us beyond the range finite-automata resources attested in other species' communi-

cation systems, corresponding to the classic argument for non-terminal symbols and recursion in Chomsky (1957) (effectively, external MERGE); and another, subsequent step, corresponding to internal MERGE, adding the resources of a Linear Bounded automaton to access the stack of the push-down automaton in a way that goes beyond the limits of the 'last-in-first-out' principle of the stack.

Note, then, that even if we grant the claim that there is no such thing as half-recursion, it doesn't follow that MERGE is equally atomic. It is perfectly possible that external MERGE and internal MERGE steps took place at different times, requiring at the very least two (macro-)mutations. It is also possible under this view that only one of the macro-mutations would be unique to modern humans.

This is where Berwick and Chomsky's argument concerning the evolution of MERGE and the modern language faculty rests on the accuracy of the Great Leap Forward view, and the claim that there was not enough evolutionary time to accumulate the relevant mutations. Even if we grant that there cannot be such a thing as half-external-MERGE, the macro-mutation giving rise to it could have taken place thousands of years before the human brain could accumulate the relevant mutations for the computational regime supporting the internal-MERGE step.

Needless to say, if we turn to the implementational level, and we try to map MERGE to the brain, which means accounting for the algorithmic requirements of a context-sensitive grammar, we will be faced with a difficult task of determining structures of the brain involved in what MERGE does, and show how they achieved the relevant, current state. At the genetic level, it becomes more and more apparent that a single mutation is incongruent with the level of complexity we are faced with, as we move from the computational to the implementational level. This is made even more apparent when one considers the non-direct relationship between genes and behavior (Fisher, 2017).

The evolution of something as complex as human language deserves integration of results and insights from different corners of the research landscape, and just like neuroscience, evolutionary theory stands to benefit from the guidance of cognitive science (Krakauer et al., 2017). This is where the *a priori* value of the single-mutant theory of language evolution of Berwick and Chomsky (2016) lies. It offers a computational characterization of language that can serve as boundary conditions for other fields interested in addressing the evolutionary question. In the terms of Hauser et al. (2014), this potentially turns the question of language evolution into a problem, as opposed to a mystery.

Obviously, interdisciplinary dialog is not a one-way street. Eventually, computational considerations must come to grips with both the insights and the data from other disciplines. In the case at hand, Berwick and Chomsky would do well to take on board all the archaeological evidence against the Great Leap Forward. They must also question the apparent simplicity of single-mutant scenarios in light of simulations showing that multiple-mutations scenarios are more plausible, even over reduced temporal windows (de Boer et al., 2019).

Berwick and Chomsky (2016) seem to bypass these empirical considerations by giving their single-mutant theory an air of logical necessity: things could not have been otherwise, because there cannot be such a thing as half-recursion. In

doing so they they eschew the fact that MERGE is intended to capture a specific sense of recursion that captures the full range of dependencies in natural languages. Such dependencies have been known since the 1950s not to be uniform, thereby admitting a layered, mosaic-like evolutionary history. Moreover, Berwick and Chomsky (2016) do not appear to fully appreciate the Marrian nature of cognitive traits (see Fig. 1). Eventually, the computational description must be linked to algorithmic and implementational descriptions that connect to the neural wetware and its molecular basis. There is no one-to-one mapping between the genotype and the phenotype. A single computational step need not
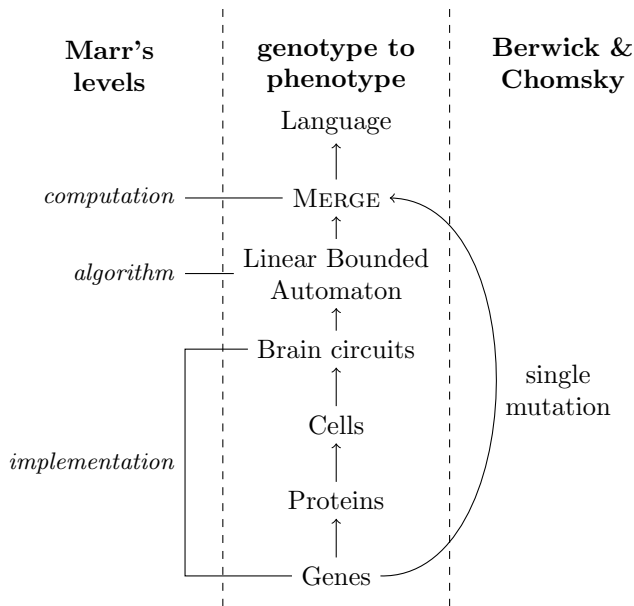

Figure 1: Berwick and Chomsky theory of language evolution in the context of Marr's levels.

correspond to a single mutation, or a single rewiring event.

As a matter of fact, we find it dangerous to rely solely on logical necessity to motivate evolutionary scenarios. Many phenotypic traits (counting, bipedalism, vocal learning, etc.) could also be said to require single-mutant evolutionary scenarios because it is hard to conceive of what the intermediate steps might be (can there be such a thing as half-counting, half-bipedalism, or half-vocal-learning)? It all depends on the underlying mechanisms and biological foundations. Evolutionary studies give us daily reasons to embrace complex scenarios, and we see no reason to abandon them in the context of language. Indeed, we think that decomposing the specific-specific trait of modern language into a mosaic of less exceptional ingredients, each with its own evolutionary trajectory, is the only way to open this line of inquiry to empirical investigation.

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