

## Article Addendum

# The biological and cultural foundations of language

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**Abbreviations:** UG, universal grammar

**Key words:** Baldwin effect, co-evolution, cultural evolution, language acquisition, language evolution

A key challenge for theories of language evolution is to explain why language is the way it is and how it came to be that way. It is clear that how we learn and use language is governed by genetic constraints. However, the nature of these innate constraints has been the subject of much debate. Although many accounts of language evolution have emphasized the importance of biological adaptations specific to language, we discuss evidence from computer simulations pointing to strong restrictions on such adaptations. Instead, we argue that processes of cultural evolution have been the primary factor affecting the evolution of linguistic structure, suggesting that the genetic constraints on language largely predate the emergence of language itself.

## Language Evolution and Universal Grammar

The human capacity for language is a hallmark of our species; the flexibility and unbounded expressivity of language is unparalleled in the biological world. But does this uniqueness stem from biology or culture? The longstanding influential biological approach sees the nature of language as determined by a Universal Grammar (UG): a genetic domain-specific neural system, analogous to vision.<sup>1-3</sup> Here, we discuss new evidence from computational simulations that challenges this perspective on evolutionary grounds.<sup>4</sup>

The standard explanation of the origin of complex biological systems is natural selection. Just as the neural substrate of vision is exquisitely adapted to the structure of the visual environment, so it seems natural to assume that UG has evolved to the structure of the linguistic environment.<sup>3,5-9</sup> The most plausible evolutionary mechanism for genetic assimilation of UG is the so-called Baldwin effect:<sup>10</sup> a trait that initially develops over the lifespan of an organism may gradually become genetically encoded across many generations, if individuals that acquire the trait faster have a selective advantage. Eventually, little or no environmental exposure is needed to develop the trait—it has become genetically assimilated.

An often-used example of the Baldwin effect is the development of calluses on the keel and sterna of ostriches.<sup>11</sup> Originally, the calluses may have been caused by abrasions where the keel and sterna come into contact with the ground during sitting. Individuals that developed calluses more quickly would then be favored by natural selection. Over generations, less and less actual contact with the ground would be needed to develop the calluses until their development became triggered in utero without any environmental stimulation.

## Evolution Favors Learning, not Universal Grammar

We explored the extent to which the Baldwin effect might lead to genes encoding a UG. Our first series of simulations showed that learners who are biased to learn a particular language differentially reproduce, and over generations, language structure becomes internalized in the genome. But there is a crucial difference between the evolution of language and vision. While the visual environment is stable, the linguistic environment is continually changing. Indeed, linguistic change is vastly more rapid than genetic change (e.g., the entire Indo-European language group has diverged in less than 10,000 years<sup>12</sup>). A second series of simulations revealed the evolutionary impact of such rapid linguistic change: genes cannot evolve fast enough to keep up with this “moving target.” Rather than genetic constraints specific to language, learning becomes key to keeping up with a fast-changing language.

Of course, co-evolution between genes and culture can occur. For example, lactose tolerance appears to have co-evolved with dairying.<sup>13</sup> But dairying involves a stable change to the nutritional environment, positively selecting the gene for lactose tolerance, unlike the fast-changing linguistic environment. A third series of simulations demonstrates that this kind of co-evolution can only occur when language change is offset by very strong genetic pressure. Additional simulations show that under these conditions of extreme genetic pressure, language rapidly evolves to reflect pre-existing biases, whether the genes are subject to natural selection or not. Thus, co-evolution only occurs when the language is already almost entirely genetically encoded.

## Cultural Evolution of Language

But if UG did not evolve by natural selection, how could it have arisen? Cosmic coincidence aside, there is no serious non-adaptationist

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evolutionary account. Hence, a language-specific, genetically encoded UG can be ruled out, on evolutionary grounds. Instead, we argue that language is primarily a culturally evolved system, not a product of biological adaptation. The biological machinery involved in language in most cases predates the emergence of language. Cultural evolution (including processes such as grammaticalization<sup>14</sup>), on our view, therefore becomes a key factor in explaining the fit between the mechanisms involved in language and the way in which language is structured and used. Crucially, though, cultural evolution does not take place in a biological vacuum but is shaped by biological constraints arising from the nature of our thought processes, pragmatics, perceptuo-motor constraints, and cognitive limitations on learning and processing.<sup>15</sup> This perspective meshes well with recent arguments in favor of taking seriously the astonishing diversity and subtlety of patterns of language across the world,<sup>16</sup> and is consistent with the proposal that language arose from the unique human capacity for social intelligence.<sup>17,18</sup>

We would like to stress, though, that our account of language evolution does not rule out all possible biological adaptations for language. Indeed, aspects of language that can be held stable over time by functional pressures—e.g., because they improve communicative efficiency or facilitate learning and processing—may become genetically assimilated (as indicated by our first simulation). The ability to learn tens of thousands of form-meaning mappings (i.e., words) may be an example of such a functional adaptation. However, functional features of language are typically not considered to be a part of UG, which instead is seen as including domain-specific linguistic properties, such as highly abstract principles governing phrase structure, case marking and agreement. These properties of language are considered to be arbitrary in the sense that they are hypothesized to defy functional explanation<sup>1,19</sup> and have even been suggested to hinder communication.<sup>20</sup> But it is exactly this lack of functional pressure that prevents genetic assimilation of UG principles (as shown by the second and third simulations).

Notice too that the richness of the various constraints on language evolution also serve to dramatically simplify the problem of language acquisition: crucially, each new generation of learners embodies the *same* constraints as prior generations—the very constraints that have shaped the structure of language over the course of language evolution. Thus, the guesses that a learner makes about linguistic structure during development will tend to be the correct ones, and language learning will be rapid, not because learners deploy a special purpose language acquisition device<sup>19</sup> or language instinct,<sup>3</sup> but because language has culturally evolved to be easily learned and processed. More generally, learning cultural forms, including language, for this reason constitutes a fundamentally different, and much easier, type of induction than learning about the non-cultural, natural world.<sup>21</sup>

In closing, we note that our results have profound implications for the language sciences. Firstly, they undercut the use of an innate UG; a core, although hotly contested, concept in linguistics and language acquisition research. Secondly, they demand a reinterpretation of the relationship between genetics, brain structures and linguistic behavior. Thirdly, they have direct implications for the origin and spread of modern humans and the development of culture, demolishing the paradigm-case of a putative “language instinct”<sup>3</sup> proposed in evolutionary psychology.<sup>9</sup> As Darwin suggested,<sup>22</sup> the evolution of human language may be best understood in terms of cultural

evolution rather than biological adaptation. Thus, whereas this year’s celebrations of the bicentenary of Charles Darwin’s birth and the 150<sup>th</sup> anniversary of the publication of the *On the Origin of Species* understandably focus on biological evolution, our results highlight Darwin’s additional important contribution to the study of cultural evolution.

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