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# Commentary: Defining and assessing constraints on linguistic forms

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## 1. The ecology of linguistic forms

In their paper, [Everett et al. \(2016\)](#) stress how a shift could or should take place from autonomous linguistic forms to ecologically adaptive ones. This raises the issue of the meaning of ecology when it comes to languages, and to what the Greek root of this word—*oikos*, the house or the habitat—actually refers.

Several authors have equated the ecology of languages with their social environment, i.e., communities of speakers. When describing the *ecology of language evolution*, [Mufwene \(2001\)](#) exemplified how situations of contact between several languages in colonial plantations resulted in specific selections and assemblages of linguistic forms. More recently, [Lupyan and Dale's \(2010\) ecolinguistic niche hypothesis](#) points at how differing social contexts may shape language structures, much as ecological niches shape organisms. They suggest in particular that a high percentage of adult L2 learners in a linguistic community may push toward less morphological complexity. Another example of social influences on linguistic forms is the debated positive correlation between the number of speakers of a language and the size of its phonological inventory ([Hay and Bauer 2007](#); [Bybee 2011](#)).

The notion of ecology can also relate to the natural environment in which speakers live and interact, as it is the case in [Everett et al.'s](#) contribution. Different phenomena can be acknowledged, which may take place simultaneously or not in specific situations.

First, as highlighted by the authors, indirect influences may be identified: different ecological settings can induce different social or sociolinguistic situations, which may in

turn partly shape linguistic forms. According to [Nettle \(1996\)](#), increased ecological risk leads to wider networks of mutual exchange and as a consequence reduced linguistic diversity and wider language areas. For [Munroe et al. \(1996\)](#), warm climates promote more frequent usage of Consonant–Vowel syllables and sonorous sounds, since they suit a predominantly outdoor life and distant communications. Intuitively, human migrations due to environmental changes may also result in language contact and change. In such cases, linguistic systems may undergo significant changes, but the causal impact of the environment may be said to be of *second order*.

Direct or *first-order* causation may take place on both sides of Saussure's linguistic sign. As for the *signified*, a language can exhibit adaptation or at least adequacy to the environment, among others in the way it may describe space with a geography-based system, offers a great diversity of lexical items to depict specific aspects of the environment, or yet uses spatial properties of the environment to express other conceptual domains such as time. For example, as detailed in [Núñez et al. \(2012\)](#), the Yupno speakers of Papua New Guinea Highlands see the past as downhill and the future as uphill, something that would be very unlikely for populations living in much flatter surroundings. Turning to the *signifier*, i.e. the linguistic signals, Shannon's sender, receiver, and channel of communication ([Shannon 1948](#)) may be summoned, since adaptation to the environment may relate to them distinctly. [Everett et al.'s](#) study of the effect of aridity on vocal folds points primarily to the emission of messages, and how a linguistic system may respond to perturbation

at this level. Everett's (2013) claim that ejective sounds are mostly found at high altitudes, due to a decrease in atmospheric pressure favoring their production, also focuses on the sender. In contrast, Maddieson and Coupé (2015) suggest that dense vegetation degrades the transmission of higher frequency sounds, and thus disfavors phonemic inventories with a large number of consonants or complex syllabic structures; what matters here is the channel of communication. Future studies could perhaps point to the reception of signals.

All in all, it makes sense to call for a broad perspective when it comes to the ecology of language. To some extent, linguistic forms 'inhabit' natural environments and linguistic communities. But they are also primarily produced, perceived, stored, and processed in individual speakers, whose brain, vocal tract, and ears are largely determined by genes which may exhibit populational variation. A good example is Dediu and Ladd's (2007) relationship between the worldwide distribution of tones and haplotypes of genes implied in cerebral growth. Constraints and partial determinism may exist at all levels, which restricts the independence of linguistic forms. The challenge is being able to decipher the entanglement of forces shaping them.

## 2. Statistical approaches: how to untangle the factors weighting on linguistic forms?

In order to highlight the different mechanisms shaping linguistic forms, statistical models are designed to predict a dependent variable such as the absence or presence of a linguistic feature on the basis of several independent variables, such as humidity, elevation, affiliation to language families or areas of linguistic contact, etc. This is encouraged by the ever-growing body of 'big data' digital datasets, whether linguistic, demographic, cultural, or environmental. As more plausible causal mechanisms are unearthed, the number of predictors to include in models increases. This trend is visible in other fields, such as psycholinguistics (Baayen et al. 2007), while disciplines such as ecology have long been familiar with it. Juggling with many predictors makes it hard to derive causal mechanisms from correlation patterns, and to correctly point at confounding variables.

Along these lines, it is important to clearly delineate direct and indirect actions of the environment on linguistic forms. There are clear ecological influences on human behaviors (Nettle 2009). Therefore, given both direct and indirect potential effects of the environment on human communicative signals, it is tempting to look for strategies that control for the relationships between environmental and sociocultural variables, so that direct influences of the environment can be singled out and

properly assessed. At the statistical level, this amounts to accounting for multicollinearities between environmental and sociocultural predictors in regression models aiming at predicting the distribution of linguistic features.

How to correctly deal with collinearity has been a subject of debate for years. Simply ignoring it is possible, but makes sense if one seeks to maximize the amount of variance explained by a set of predictors, much less if the significance of a specific predictor is being assessed. Regarding climatic and social variables, it seems, for example, tempting to first predict the distribution of linguistic features with social predictors only, and then use the residuals of this first regression as the dependent variable of a second model with climatic variables as predictors. Since the residuals of a model are by nature uncorrelated with its predictors, this two-step approach apparently offers a good control for social phenomena, since the effect of climate is estimated on a predicted variable that has been 'cleaned' of their influences. Canceling out collinearity in this way is a technique named *residualizing*. It has been used across various scientific fields, including in attempts to estimate the role of environmental factors on phonological inventories (Coupé et al. 2013). However, several authors have clearly pointed out the misunderstandings behind its use (Freckleton 2002; Wurm and Fisiocarò 2014), and argued that it should be discarded in most situations. The standard strategy is to rely on the so-called 'type III sums of squares', which assess the significance of each explanatory variable given that all other variables have been controlled for. This is what is commonly done in regression models, although it is not always explicitly mentioned. Significant main effects may thus be revealed, but some argue that they are uneasy to interpret if significant interactions exist between the predictors, and are not given proper consideration.

Without going too far into technical details, one should remember that it does not always make sense to conceive of hypothetical situations in which two variables which co-vary in real life are made independent for the sake of analysis (Anderson 1963; Breaugh 2006). Once again coming back to environmental and sociocultural predictors, if enough contrastive situations can be identified and included in the data, collinearity should be low enough as to be correctly dealt with. Otherwise, the issue is more ontological than technical.

Taking geographic distances between languages into account is another statistical issue. Closely located languages may be in contact and borrow linguistic material from each other, unlike more distant languages. However, these latter may also be connected because of long range past human migrations and their role in linguistic inheritance. Leaving these phenomena aside can lead to wrong

conclusions regarding the role of the environment. A common strategy to account for geography is to consider continents or other large areas as an independent variable in regression models. However, this does not seem the best way to correctly account for short-distance effects of geography on languages. Spatial regression (LeSage and Pace 2009; Anselin and Rey 2010) seems a better candidate, since it estimates the degree of spatial dependency at the level of the dependent variable. Variograms are a common tool to represent this dependency according to distance. Regarding the geographic distribution of tonal languages, for example, one can wonder at which spatial scale breaks and boundaries are best observed. This spatial knowledge is what is injected into regression models to better control for spatial nonindependence.

A compounding problem when it comes to languages lies in the relationship between space and history: geographical locations and genealogies often go hand in hand around the globe, and two neighboring languages are likely to share a rather recent common ancestor. Many regions of contact between language families obviously contradict this pattern, as well as linguistic groupings such as the controverted Altaic family, with related languages scattered over extremely vast areas. Again, a strong correspondence between two predicting factors may blur causal mechanisms. Assessing both geography and genealogy is possible in models, but results may be dependent on the specific way this is done: adding random effects rather than fixed effects for genealogy, using covariance structures or fixed effects for geography, etc. (Jaeger et al. 2011). For example, adding genealogy in a model can sometimes completely erase spatial auto-correlation in the residuals. This suggests that spatial regression models are unnecessary, but one can then wonder whether a ‘genealogy-only’ story is the proper one, given all what we know about situations of language contact. Comparative studies sharing the same dataset would be welcome to assess the respective qualities of competing options.

The depth of the linguistic genealogy considered in the model is relevant. The previous statement on neighboring languages sharing common ancestry becomes trivial if one considers very deep ancestry. In the same way large areas entered in models as predictors may not be the best way to account for space, considering only large groupings of languages may also leave aside interesting phenomena occurring closer to the leaves of the tree. Relying on the structure of linguistic phylogenies to account for genealogical relationships seems an attractive option, following what is done in evolutionary biology. However, language trees are not as clearly specified in terms of time depth and branch length as those built by biologists, which may be an issue.

Overall, despite much progress in current statistical approaches, there is still room for improvement. Stronger collaborations between linguists and statisticians seem a very logical step to move forward.

### 3. Human language and animal communication

Language is an inferential system of communication rather than a code (Sperber 1994), and the massive amounts of cognitive processes underlying the coding and decoding of linguistic signals make them more robust to variation and perturbation. Looking at the influence of climate or of other environmental factors hides this important difference with most animal communication systems. This does not mean that effects should be considered as spurious, but rather that it is hard to estimate the balance between inferential processing and reliance on the communicative signals themselves. The fine interplay between production and perception, and between construction and deconstruction of messages, should be seen as related to the amount of selective pressure applied to linguistic forms: our capacity to overcome variations in the shape of signals could partly explain why even weak selective forces such as those of climate eventually visibly impact linguistic systems.

In animals, what is being communicated and how can be partly assessed. In some cases, it is possible, given sufficient understanding of the code, to observe that different contents of the communication signals propagate differentially in terms of distance, in an adaptive fashion: in white-browed warblers, for example, it has been shown that species-identification signals are perceived over long distances, while other aspects, such as individual identity, can only be identified at close range (Mathevon et al. 2008). Could such distinctions be made in human languages? Are there words which are used significantly more in close interactions, and others in more distant ones? If yes, do they exhibit distinctive phonetic properties that could be related to environmental influences?

Investigations such as Everett et al.’s should be encouraged and assessed with the proper recognition of the advantages and limitations of their technical stances. Neither should one discard them on the basis of an apparent heretic positioning, nor should they be considered as the new and only way to do proper linguistics in an era of numbers and models. Rather, their potential to deepen our understanding of human communication should be noted, and properly evaluated in the course of open-minded debates touching a wide range of disciplines.

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# Commentary: Is the effect of desiccation large enough?

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I certainly agree with the authors (Everett et al. 2016) that the question whether there is an environmental

influence on the sound systems of languages (or on other aspects of language) is worth investigating and that the