Into thin air: A return to ejectives at high altitude

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Abstract

This paper presents new evidence for the strong association between ejectives and altitude, obtained via examination of a database with 3700+ languages. I address common objections and misconceptions regarding the correlation in question.

Introduction

In June of 2013, I published a paper in PLoS ONE offering evidence for direct geographic influences on human sound systems. The article's publication was met with extensive coverage in the media. Some of this coverage was sensationalistic, some of it reasonable. In addition, as one blogger put it, there was "a flurry of excitement, and not a little criticism" surrounding the paper in the linguistic community. Some of this criticism was also quite reasonable, while some of it was transparently flawed. Interestingly, a number of objections were raised under the presumption that the ejectives-altitude correlation is the only demonstrable global correlation between geography and phonology, and just happens to be one of the spurious correlations you'll find if you look at a large database long enough. In fact, the correlation was simply one of several recent findings on the interaction between geography and human sound systems. In other work in its final stages, some colleagues and I offer other evidence for geographic influences on phonologies. In contrast to the ejectives-altitude correlation, the other associations are buttressed by relevant experimental data. Hopefully they'll be coming to a journal near you in the not-too-distant future. Close inspection of the data in those papers is more likely, I think, to convince skeptics that human languages can adaptively evolve in accordance with characteristic conditions in the ambient air of some geographic regions. In fact, as we suggest in the other papers, the assumption that phonologies could be ecologically maladaptive in a way that other forms of human behavior are not is poorly grounded. It simply doesn't mesh with actual empirical work on human physiology and behavior. Extensive research in laryngology has demonstrated, for instance, the deleterious effects of desiccated ambient air on precise phonation. This implies that certain sounds are less efficient physiologically in certain ecologies (in ways I won't delve into here). My own view, and that of a number of researchers who have corresponded with me since the publication of my article, is that it is time linguists began paying careful attention to the potential influences of such factors on human language. This is especially true since no convincing arguments have been presented in the literature as to why language would be uniquely maladaptive among the suite of human behaviors, and since the study of sound systems has not carefully considered the geographic-phonological associations discussed in the work of myself and others. It is also true since the communication systems of other animals (particularly birds) are known to be ecologically adaptive.

Many linguists conservatively interpreted the ejectives/altitude correlation as epiphenomenal. This is understandable to some extent since, as I acknowledge in the article in PLoS ONE, the motivations I offer for the association have not been supported experimentally. In fact, I explicitly state that either, both, *or neither* of the suggested motivations may be at work in creating the interesting clustering of languages with

ejectives in high-elevation regions. The assumption in the article is that it is unlikely that a correlation between a non-pulmonic sound and reduced ambient air pressure (or hypoxic conditions) would develop by coincidence, especially in the robust way it has across major landmasses. It seems odd to me that some researchers were willing to discard a causal relationship prior to experimental exploration, since experimental data of various sorts could shed light on this topic. Only via such experimental reconnaissance could we confidently claim that the association is in fact fabulously coincidental. We are all well aware, after all, that spurious correlations exist, and that there are potential issues with nomothetic studies. Some of these issues are discussed in detail by Roberts and Winters (2013) in their recent PLoS ONE paper. Yet, as those authors also acknowledge, the discovery of global correlations can play a pivotal role in spurring on experimental work on a given topic. This is especially true when there is a clear testable ligature between two variables, as there is in this case. It is also particularly true when a given correlation is predicted. After all, predictable correlations tend to be of a very different sort than spurious correlations resulting from confounding factors. The assumption (by some at least) of spuriousness, given the nature of the association presented in my article, reflects an unsupported bias towards the position that sound systems cannot be impacted diachronically by environmental factors. Particularly in the light of other recent research on this topic that is consistent with extant experimental work, this bias needs to be questioned. (Feel free to email me if you're curious about that other research.)

The purpose of this somewhat informal paper is to further demonstrate that the association between ejectives and altitude is very real. While many readers acknowledged the correlation and even offered additional support for it by controlling for phylogenetic factors in different ways, some suggested that the correlation was a byproduct of the metrics chosen to represent 'high elevation zones' in the paper. This reflects a superficial reading of the article, for the following reasons: First, the paper presents evidence on clusters of ejective languages, which are visibly associated with regions already described in the geography literature as high elevation zones. Second, the paper also describes differences in the absolute elevations of languages with and without ejectives, differences that do not rely in any manner of the 'high elevation zones' as described in the article. Third, the figures of 200km and 500km utilized in the article were chosen to show the association between reduced distance from high elevation and languages with ejectives. The association was evident regardless of which distance was selected, and other arbitrary choices would have led to the same conclusions, as evidenced by any reasonably close inspection of the data in the paper.

Nevertheless, it seems worthwhile to return to this topic, and to demonstrate that the association is quite real and merits further exploration. To do so, I'll be employing the Phonotactics Database of the Australian National University, since it includes pertinent information for 3700+ languages. I'll focus on the status of ejectives in language isolates and within language families, as means of mitigating phylogenetic influences. Some points of contention raised after the article's publication are self-evidently flawed and not discussed in detail here. For instance, some blogs suggested that OV word order correlates with altitude more than ejectives, as though one correlation should invalidate another. However, what those blogs (first Replicated Typo and, subsequently, Language Log and others) crucially ignored is that the OV-elevation correlation is not significant once areal and phylogenetic factors are accounted for, and is largely driven by the overwhelming presence of OV languages on e.g. the Tibetan plateau. It does not surface systematically across continents. In effect then, the only other feature of the WALS database to putatively correlate with high altitude does not do so in near the same way that ejective-presence does, **lending further support to the claim that this correlation has special status.** In

addition, several readers suggested that the correlation may be due to the isolation of languages in mountains, which are somehow more likely to retain 'odd' sounds like ejectives due to reduced inter-linguistic contact. This would be an interesting finding in and of itself, and would offer strong evidence for an indirect influence of geography on phonology, but it too is transparently flawed. It does not explain why, for instance, implosives (which are about as common as ejectives), or any number of other sounds, do not correlate with high elevation. Finally, some suggested that population size may be a factor in motivating the preponderance of ejectives at high altitude, but the factors involved in such an association (which would, again, demonstrate a heretofore-unknown indirect relationship between geography and phonology) are unclear, and there has already been extensive work (see Moran et al. 2012) demonstrating an absence of a true association between population size and phonemic inventories.

So let's stick to the main issue at hand: Is there evidence for the association in a database of over half the world's languages? In addition, is there evidence that the correlation operates independent of phylogenetic effects? In the case of both questions, we will see that the answer is a resounding yes. The data I present here are more difficult to reconcile with the claim that the association is spurious, and particularly difficult to reconcile with the notion that the association is somehow not significant.[1]

Analysis of ANU data

Of the 3755 languages in the ANU database, only 320 have ejectives. This proportion is substantially lower than that in the WALS database, due in part to the comparable overrepresentation of languages of Australia, New Guinea, and the Pacific in the ANU database. Nevertheless, there are over three times as many languages with ejectives in the ANU database, allowing for a more robust analysis of their elevation. The global distribution of languages with and without ejectives is presented in Figure 1.

[1] In a forthcoming paper, a geographer colleague and I analyze this association with some more nuanced techniques (not employed here) that also account for phylogenetic and areal influences, techniques that offer further support for the association.

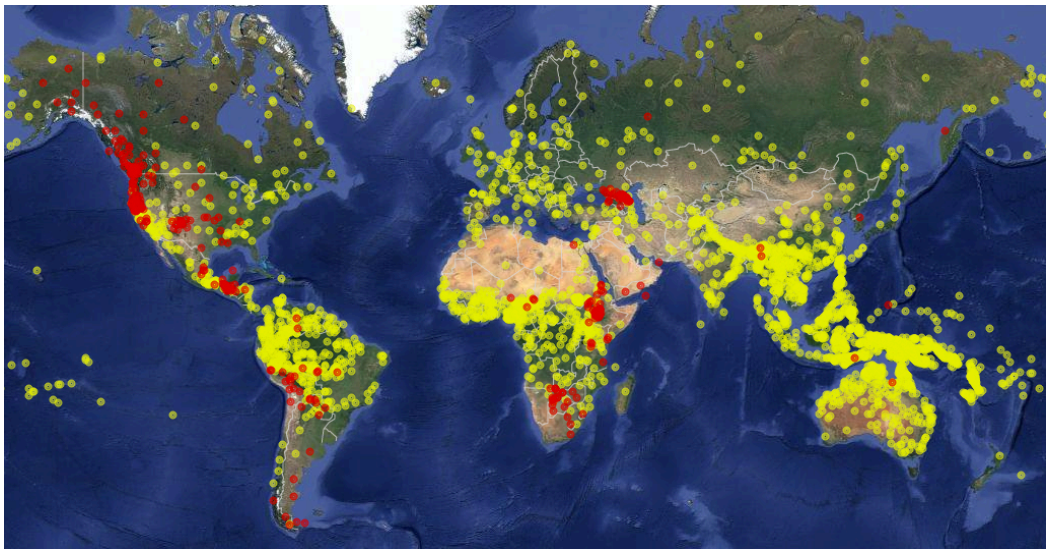

Figure 1. Red dots= Languages with ejective. Yellow dots= Languages without ejectives.

The distribution of the 320 languages with ejectives is not surprisingly quite similar to the distribution of languages in the independently coded WALS database. Languages with ejectives cluster on the Javakheti Pleateau, along the North American Cordillera, along the Andes, on the Southern African Plateau, and in the highlands of the East African Rift. There are some exceptions to this tendency of course, but not many. (Interestingly, a number of exceptions are in desert climates—see discussion of water vapor loss in the original article.) 93 of the languages with ejectives are at high altitude (above 1500m), while 227 are not (41%). In contrast, 341 languages without ejectives are at high altitude, while 3113 are not (9.8%). Overall, the data pattern in the predicted direction, though such a basic breakdown does not account for areal or phylogenetic factors in any manner.

One simple way to account for phylogenetic and areal influences is to examine the distribution of **language isolates**. According to the ANU database, there are 33 language isolates with ejectives. Of these, 9 are at altitude, or 38%. Conversely, there are 92 isolates without ejectives, but only 7 (8.2%) of these are at 1500m or greater. This disparity is significant according to a Fisher's exact test (p=.01), assuming (fairly, I think) that these isolates represent independent data points. Tellingly, the distribution of isolates is not dissimilar from the distribution of all languages. This fact suggests strongly that the association is not simply due to phylogenetic factors. It is also not simply due to areal factors, since the isolates are generally not geographically proximate to each other. (The exceptions to this tendency do not benefit the association, since there are two potential clusters of isolates, one in New Guinea without ejectives, and one in North America with ejectives but at low altitude.) To illustrate that the significance of the within-isolates disparity is not due to any artificial manipulation of what it means to be at 'high altitude', i.e. a 1500m figure, consider that the mean elevation of languages with ejectives is 887m, while for those without ejectives it is 457m. This disparity is significant (p=0.004), according to an unpaired two-tailed t-test. While the status of some of the isolates in the ANU list is debatable, it seems clear that the languages in question are not related to each other. Furthermore, one clearly debatable case, Korean, operates against the trend in question. In addition, the low mean altitude of isolates without ejectives obtains despite the inclusion of one outlier, Burushaski, that is at extremely high altitude.

Inter-linguistic factors are obviously at work in the distribution of this sound type, as they are with any phonemic category, and languages have of course been documented to borrow ejectives from other languages. A number of readers have suggested that this sort of well-known factor should in and of itself cast doubt on the analysis in my PLoS ONE article. In doing so, however, they seem to have missed the key question raised by the article: **Why** are the regions in which we see ejectives preserved through inter-linguistic borrowing (and other processes) at or near high elevation? Framed differently, why have high altitude regions exerted a diachronic gravitational pull on the distribution of this sound type? The claim was certainly not made that languages should only borrow ejectives at high altitude, much as it was never claimed that ejectives should surface in all high altitude regions. The claim was and is that languages with ejectives only cluster in high elevation regions, and given the physiological mechanisms involved in the articulation of ejectives, it seems remarkable that they cluster in the manner they do.

The mean elevation of languages with ejectives in the ANU database is 1028 m, while the mean elevation of languages without ejectives is 601m. This disparity is actually more pronounced than that observed in the WALS data, however it does not account for phylogenetic factors or areal factors. Some have objected to the use of precise locations for language locales, given that speakers obviously move around a lot, and given that terrain can vary significantly even in small areas. For that reason I (with the help of a geographer), obtained the mean altitude of 100 sq. km plots of land surrounding each language location provided in the ANU database. I did the same for 500 sq. km plots of land. These figures were found via ARCGIS. The results are presented in Table 1.

Table 1. Mean elevation language locales and surrounding areas

	100 km plots	500 km plots
With ejectives	1045 m **	947 m **
Without ejectives	587 m	588 m

As we see, the finding obtains even if larger surrounding areas are considered. Now let's see if the finding obtains within continents, as suggested in the PLoS ONE paper. I recognize that a continent-by-continent analysis alone doesn't completely control for phylogenetic or areal influences (though it severely mitigates such influences), but am simply establishing that the same sort of analyses carried out in the original paper lead to similar results with a larger database, and that the pattern in question is not due to the distribution of languages on one or two landmasses.

Table 2. Mean elevation of language locales (for 100 sq. km plots), across continents

	Africa	Eurasia	S. America	N. America
With ejectives	1171 m ** (N=70)	1332 m ** (N=56)	1293 m ** (N=32)	846 m ** (N=156)
Without ejectives	562 m (N=485)	1072 m (N=810)	471 m (N=358)	632 m (N=181)

Note that, according to the ANU data, the disparity between languages with and without ejectives is highly significant on each major landmass, even in terms of absolute elevation. In contrast, for the PLoS ONE paper the disparity was not found for N. America, at least not

with respect to absolute elevation. In other words, **the pattern is actually more robust in the larger database**. It is readily apparent even if we do not rely at all on "distance from high elevation zones" as I did for some (though not all) of the analyses in the PLoS ONE paper.

Of course such findings do not account for all confounding influences, since some influences operate within continents. One could conservatively assume that it is simply coincidence that the pattern surfaces on four continents, and that certain language families with ejectives just happen to be at high altitude. This is problematic since predicting a correlation on four separate continents would be remarkably lucky, and since we have already observed that the pattern holds among isolates. There are other ways to account for phylogeny, of course. Some quantitatively robust ways have been adopted in reanalyses of the WALS data, for instance by Sean Roberts at Replicated Typo. Those analyses have actually found strong evidence for the association even after accounting for phylogenetic factors. (See footnote 1 regarding other forthcoming work on this topic.)

Admittedly, though, there is disagreement on how best to account for phylogenetic factors, with various implicit assumptions made depending on the kind of phylogenetic analysis chosen. One method is simply to examine the distribution of ejectives among isolates, as we have already done. Another is to consider the distribution of ejectives within particular language families. It has been claimed by some that diachronic data are difficult to reconcile with the notion that there is a causal relationship between altitude and ejectives. However, the counter-claims in question are based on hand-picked putatively exceptional diachronic cases. Such exceptional cases are interesting but hardly constitue dispositive counter-analysis, particularly since my PLoS ONE article makes **no claims about the time-depth** of the evolution of the association in question, and since it is of course possible that there are exceptions to the tendency. It is after all a **tendency**, one that surfaces on a global scale, and that I suggest requires further exploration. Picking and choosing diachronic cases favorable to one's perspective is easy to do. I could point out, for instance, that the urheimat of Proto-Uto-Aztecan is estimated to be coastal (Wichmann et al. 2013), and note that the fact that many Uto-Aztecan languages are at high altitude today (but do not have ejectives) helps account for the comparable weakness of the tendency in N. America. I could also observe that Salishan languages overwhelming have ejectives (even at low altitude), and that the urheimat of Proto-Salishan was indubitably in a mountainous region, so its speakers would have regularly spent time at high altitude. Yet precise estimates of proto-language homelands remain contentious in most cases, as do a number of diachronic claims in some putative counter-analyses regarding the association of ejectives and altitudes. Perhaps the most crucial test cases, then, are language isolates, which as we saw above support the association quite clearly. Yet there are other quite relevant test cases, in which we can examine diachronic data without relying too much on contentious urheimats: Large families that have some languages with ejectives and some without, with numerous representatives at high altitude and at low altitude. What do such cases suggest? There are really only two of them: Afro-Asiatic and Niger-Congo. Figures 1 and 2 represent the distributions of these two important test cases.

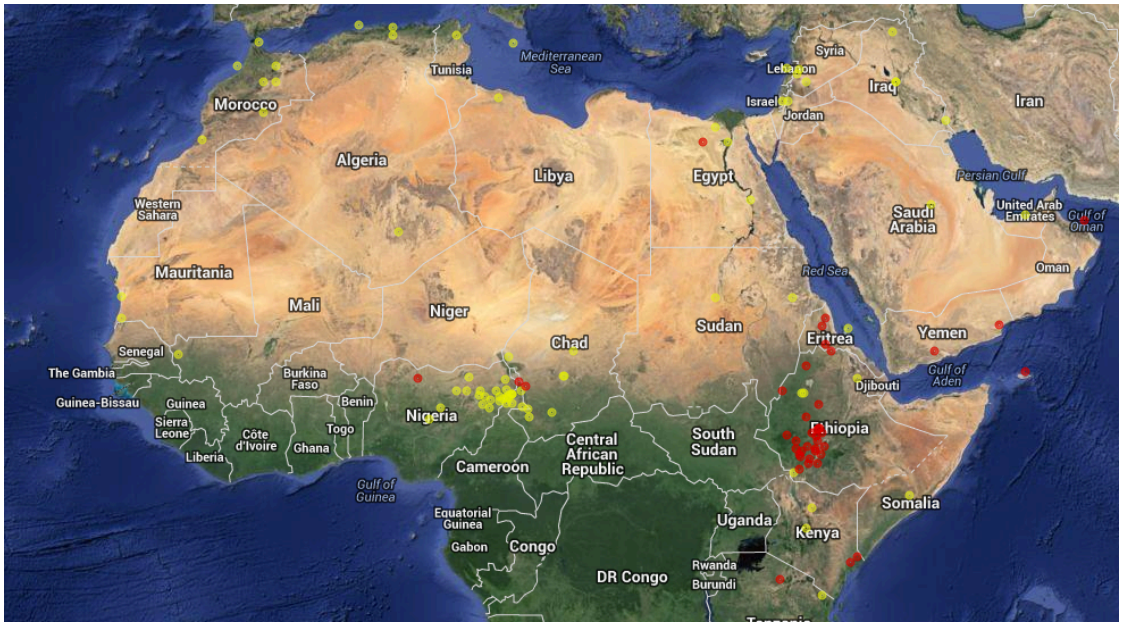

Figure 2. Distribution of Afro-Asiatic languages. (Red dots=languages with ejectives)

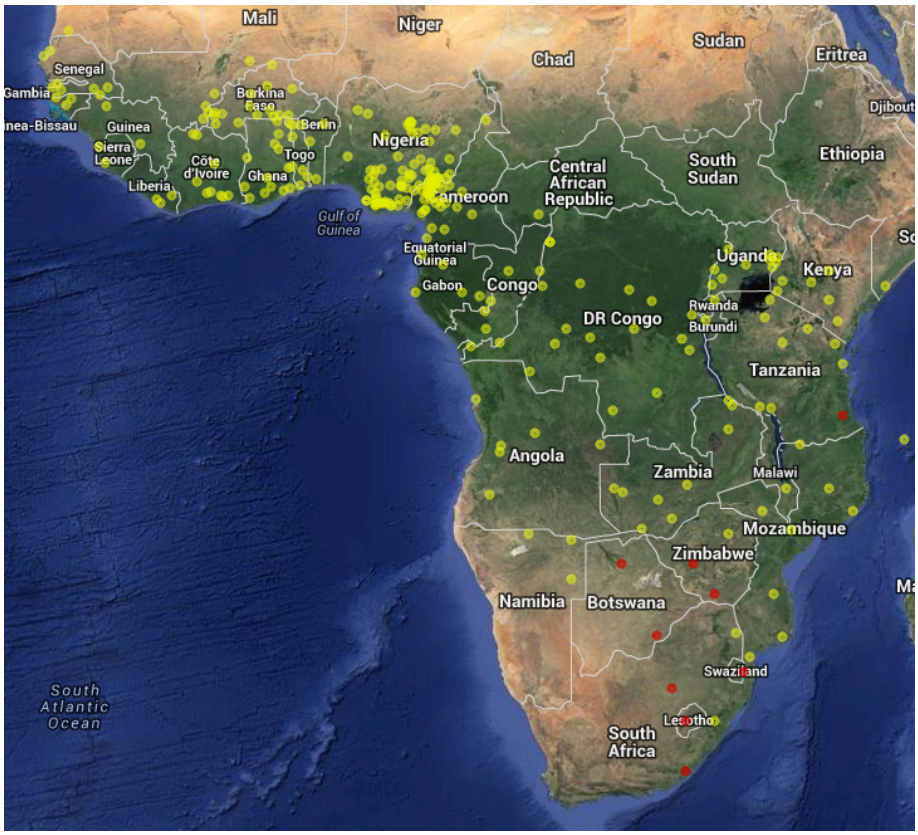

Figure 3. Distribution of Niger-Congo languages. (Red dots=languages with ejectives)

Table 3. Mean elevation of language locales (by 100 km plots), for two language families.

	Afro-Asiatic	Niger-Congo
With ejectives	1267 m **	926*
Without ejectives	527 m	526

Niger-Congo is particularly telling, since the urheimat of Proto-Niger-Congo is uncontroversially located in West Africa. Interestingly, though, the Niger-Congo languages on the Southern African Plateau have gained ejectives. One could of course claim that this is coincidental, due to contact with Khoisan languages. But here again we see how such counter-claims based on areal contact simply beg the question. Why is it that ejectives tend to be available for borrowing in or near high elevation regions? It seems likely that some factor must etiologically motivate the association we are seeing synchronically, particularly given that it operates within language families.

In short, the within-language family data for the two major test cases are actually quite consistent with the claim that the association is real, and not due to phylogenetic factors. Just as the association is clearly not due to the distribution of languages with ejectives in one or a few particular linguistic areas, it cannot pithily be ascribed to phylogenetic influences.

Conclusion

In sum, there is a very real correlation between languages with ejectives and regions of high altitude. **It surfaces in 3700+ languages, within each major landmass, within language families, and is evident across language isolates**. Of course, to fully explore this correlation, experimental inquiry is required. I offer two potential motivations for the correlation in the PLoS ONE paper. Another hypothesis is that ejectives somehow facilitate oxygen uptake in hypoxic environments. It is known, for instance, that breathing against a closed glottis (the Valsalva maneuver) offers some benefits during respiration, and it is not unreasonable to speculate that ejectives may impact expiration in a health-beneficial manner. Such a speculative account could also be tested experimentally. Given that the demonstrated correlation is between a sound that doesn't require pulmonic air, and given that high altitude populations have been shown to have different respiratory patterns (see the work of Cynthia Beall and colleagues), such possibilities simply cannot be discarded *prima facie*. Rather, they suggest a fascinating *potential* ligature between linguistic patterns and respiratory behavior.

Finally, the assumption of spuriousness is problematic even if this were the only evidence of geographic influences on sound systems. Yet, as interested parties are likely to find out in upcoming months and years, there is more evidence to be brought to bear as researchers address this lacuna in our linguistic awareness. The evidence is beginning to suggest that human sound systems, like other behavioral exaptations of biology, are in some ways adaptive vis-à-vis ecological factors. Language researchers have not generally considered this possibility in the past but, to be fair, they have not been aware of the global associations between sounds and geography that new databases (such as WALS, ANU and PHOIBLE) are allowing us to explore. Nevertheless, one wonders why some would be reluctant to consider the possibility that the articulation of language, a pervasive behavior requiring the continuous engagement of the upper respiratory tract, is susceptible to adaptive pressures otherwise operative in the behavior of humans and other species.

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