Towards a Phonetic Explanation for Universal Preferences in Implosives and Ejectives

Author(s): Hector Javkin

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TOWARDS A PHONETIC EXPLANATION FOR UNIVERSAL PREFERENCES IN IMPLOSIVES AND EJECTIVES

Hector Javkin
University of California, Berkeley

Glottalic consonants are produced by closing the glottis and using movements of the oral cavity, particularly the upward or downward movements of the larynx, to compress or rarefy the air in the oral cavity. Implosives involve a downward movement of the larynx and produce a relatively low pressure; ejectives involve an upward movement and produce a compression of the air in the oral cavity. Haudricourt, in 1950, first noted that implosives and ejectives show strongly opposite tendencies for place of articulation. Languages show a preference for ejectives in the order: velar, alveolar, labial, while implosives occur most often in the opposite order. Greenberg, in an extensive work in 1970, firmly established these tendencies and put them into implicational relations. He found that a language will only have velar implosives if it has alveolar and labial implosives; it will only have alveolar implosives if it also has labial ones. For ejectives, the opposite implications hold: a language will only have labial ejectives if it has alveolar and velar; it will only have alveolar if it has velar.

Despite some counter-examples found by Campbell (1973) in some Mayan languages, Greenberg's observations seem to be correct. The tendencies were generally confirmed in a count conducted by the Stanford Phonology Archive, which appears below.

Stops	Labial	Alveolar	Palatal	Velar	Uvular
Implosive	17	15	2	2	0
Ejective	26	29	7	31	15

It should be noted that palatals and uvulars do not maintain these tendencies, since these places of articulation tend to disfavor stops. Secondly, although the numerical preferences for ejectives at the three major places of articulation do not seem overwhelming, the implicational relations still hold in the languages in the archive, thus upholding Greenberg's claim.

The fact that this tendency holds in so many languages suggests a phonetic basis. It is not surprising, then, that phonetic explanations have been suggested for this tendency. What is surprising is that there has been relatively little phonetic data on these consonants, and that so much remains to be done in finding the correct explanation.

Wang (1968:8) suggests the following:

"...there seems to be a tendency for compression to occur with smaller volumes of air, while rarefaction occurs with larger volumes. This may account for the fact that labial ejectives are comparatively rare, and that velar implosives have not been reported."

Greenberg, in a footnote, acknowledges benefitting greatly from a discussion with Wang concerning the phonetic basis of some of the tendencies involving these sounds. A few paragraphs later, he says (1970:139):

"The point of articulation hierarchies of ejectives and injectives are obviously based on preference for a small and large air chamber, respectively. It is also clear that with the same thoracic pressure it is easier to build up compression in a smaller chamber. Injectives are usually voiced and involve leakage of air through the descending cords; such leakage is more easily tolerated from a large chamber."

Finally, Ladefoged (1971:43) cites Greenberg's explanation as the basis for these tendencies.

I shall ignore the confusion evidenced by the last line quoted from Greenberg; it is obvious that, given that implosives rarefy the air in the oral cavity, air will leak <u>into</u> the cavity, not <u>from</u> it. As a whole, the explanation (which I will treat as a <u>single</u> explanation which is probably clearest in Wang) appears to say that compression is favored in a small chamber, and that rarefaction is favored in a large chamber. This explanation seems to have been the result of a misunderstanding of a simple concept in physics.

According to Boyle's Law (Boyle,1662), in a closed chamber, pressure is inversely related to the volume of gas in that chamber. This seems to have led Wang, Greenberg and Ladefoged to conclude (correctly) that it is easiest (requires the least change in size) to produce a compression in a small chamber, and to conclude (incorrectly) that it is easiest to produce a partial vacuum in a large chamber. The error of this conclusion can be demonstrated easily. If a small plunger is attached to, let us say, the Houston Astrodome and the plunger is pulled out one centimeter, the vacuum produced will be minimal, and insufficient to produce a sound when a door is opened. If the same plunger is now attached to a small pill bottle and the plunger is again pulled out one centimeter, a reasonable popping sound should occur when the bottle is opened. It takes the same effort to produce a rarefaction or a compression in a chamber of the same size. This means that the explanation for ejectives should hold for implosives as well, and that both types of sounds should have the same preferences for place of articulation. This is obviously not the case.

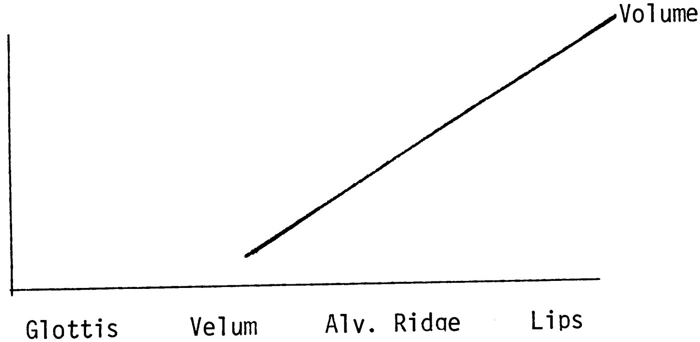
There are two explanations which I would like to suggest, although I do not believe that we presently have sufficient data to choose between them. The first explanation assumes that the only action to change air pressure involves the movement of the larynx, with some accompanying changes in the diameter of the pharynx. Ejectives, under this view, can still be explained in terms of air pressure, since it is easier to produce a compression at the velum than at the alveolar ridge, and easier to produce a compression at the alveolar ridge than at the lips. In the case of implosives, physiological factors take over. Ladefoged (1968) has noted that the hyoid bone, which is attached to both the larynx and tongue root, moves downward to a considerable degree during implosives, presumably because it is pulled down by the lowering larynx. Such downward movement of the hyoid might be antagonistic to a velar closure, since lowering the hyoid, and simultaneously raising the tongue root, might be extremely difficult given that the two structures are attached. The more limited raising of the tongue body required for alveolars and palatals would be somewhat affected by the lowering of the hyoid, although the effect would not be as great as that for velars. Finally, labial implosives, not requiring tongue raising at all, would not be adversely affected at all by the actions of the hyoid. This would account for the observed hierarchy, since there would be greater antagonism between the lowering hyoid and the movements of the tongue, as one moved progressively away from a labial articulation.

If this is correct, we should also revise the explanation for ejectives, in that the raising of the tongue body would probably produce a pull on the larynx that would help it rise in the case of velars and alveolars. Since the air pressure preferences work in the same direction, it would seem that the two mechanisms, tongue-pull and pressure, are working in concert to produce the observed preferences. In the case of implosives, the tongue-pull mechanism and the air pressure mechanism work against each other, with the tongue-pull winning out.

This explanation seems plausible, although it may have some problems. If there are two mechanisms working together in ejectives to create the observed pattern, and two mechanisms working against each other for implosives, one would expect the pattern for ejectives to be more pronounced than the one for implosives. This is not the case, as we saw earlier. The pattern for implosives is quite pronounced, while the one for ejectives is not. Furthermore, Ladefoged's data showing that some labial implosives are velarized (Ladefoged,1968) casts some doubt on the explanation. One would not expect velarization, which involves tongue-raising, to occur as a secondary articulation in a sound which made it difficult to raise the tongue body.

Another explanation resembles the Wang-Greenberg-Ladefoged explanation in that it involves the different size cavities created by closures at the different places of articulation, but it adds crucial arguments involving differences in the ability to change the size of those cavities. A plot of the size of the different cavities created by closure at different places in the mouth would look something like the following:

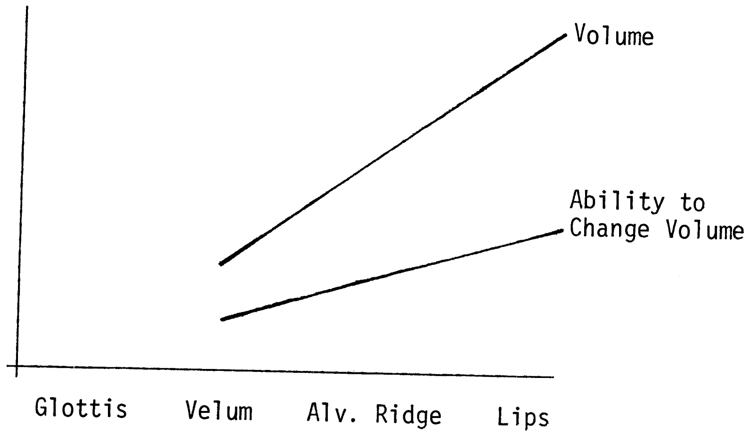
Fig. 1



There are data suggesting that the lowering of the larynx is not the only mechanism available for changing the size of the oral cavity during implosives. Although the data come from experiments with voiced stops, these also involve some expansion of the oral cavity and may allow us to make some inferences. Bell-Berti (1975) noted that the vocal tract expands for voiced stops not only by the lowering of the larynx, but also by the widening of the pharynx and the raising of the velum. Furthermore, Bell-Berti suggests that data from Fujimura et al (1973) which shows a greater area of contact for /t/ than for /d/, may be associated with an expansion of the oral cavity during voiced stops.

It is very likely that implosives, requiring a greater expansion of the oral cavity than voiced stops, use at least the same mechanisms used by voiced stops for increasing the size of the tract. Implosives would be likely to use not only the lowering of the larynx, but also mechanisms for expansion further forward in the mouth. Some evidence for this comes from Greenberg (1970) who notes that implosives show a strong tendency toward apical rather than blade articulation, and also toward retroflexed articulation. This suggests that the parts of the tongue not forming closure are being lowered to expand the oral cavity. In addition, at least in my own production of labial implosives, there is invariably a lowering of the jaw, which would also increase the size of the cavity. However, not all of these mechanisms for increasing the size of the oral cavity are available for all implosives. An implosive produced at the velum would only permit the expansion of the pharynx and the lowering of the larynx, since a raising of the velum would simply force the tongue to move to a higher position. Thus the raising of the velum is only available to places of articulation further front than the velum. Lowering of part of the tongue blade, as a mechanism for increasing the oral cavity, is only available to articulations at the alveolar ridge or further forward. Finally, labial implosives can involve the lowering of the jaw, which will cause a considerable change in the size of the oral cavity. We can plot the ability to change the size of the cavity against the size itself:

Fig.2

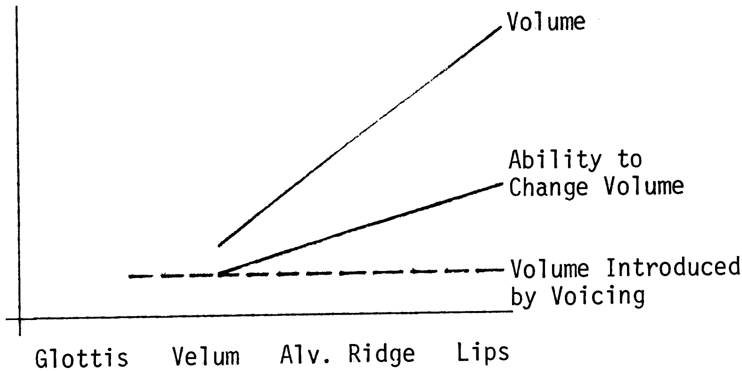


It can now be seen that the change in pressure will be greatest at places of articulation further back in the vocal tract. This is because the ability to change the size of the oral cavity is a larger fraction of the size of the cavity at places relatively far back in the oral tract. Note that this means that the oral cavity has a greater potential to create a pressure change with articulations closer to the glottis. Taking another point of view, for a given change in pressure, the articulatory organs will have to use a smaller percentage of their capacity to change oral cavity size. Presumably, this means that it would be easier to form an ejective relatively far back in the mouth.

This explanation, like the one suggested by Wang and taken up by Greenberg and Ladefoged, might seem to run into trouble with the implosives, since, once again, it would seem that a greater amount of pressure change would be achievable at the back places of articulation. However, for implosives, voicing is almost always present, and this changes the situation.

First, let us note that implosives involve the production of a stop closure with oral pressure relatively close to outside air pressure (Ladefoged,1971). Voicing during an implosive allows air to enter the oral cavity. Since the pressure is close to outside air pressure, the expansion of the oral cavity and the entrance of air into the cavity must cancel each other out. However, the effect of voicing should be approximately the same for all places of articulation. I will plot this effect, together with the size of of the different cavities and the ability to change the size of the different cavities:

Fig. 3



If these relationships hold, velar implosives can barely maintain a relatively low pressure. Alveolar implosives would have a much easier time, and labials would have the easiest time of all. In other words, it may take most of the capacity of the oral cavity for change to maintain pressure equal to outside air pressure during velar implosives. It must take a smaller proportion of the ability for change to do the same for alveolars and labials. This should mean that front articulations are easier to produce than back articulations for implosives.

It is difficult to choose between these two explanations. The second explanation is supported by the counter-examples noted by Campbell (1973), which all involve voiceless uvular implosives. The explanation predicts that any voiceless glottalic consonant, be it implosive or ejective, will favor a back articulation, so that uvular implosives confirm the explanation as long as they are voiceless. The tongue-pull explanation favors ejectives toward the back and implosives toward the front regardless of voicing, so that it should disfavor an uvular implosive. Both explanations suffer from Ladefoged's data showing that the Igbo labial implosive involves velarization. Within the tongue-pull explanation, as already mentioned, one would not expect velarization of a sound that disfavors raising of the tongue body. The second explanation is also disconfirmed by velarization since it assumes that there will be a downward movement to increase the size of the oral cavity rather than the upward movement involved in velarization. These questions will not be answered until the physiological facts of tongue-pull and the aerodynamic facts are better known. Until that time, however, we can at least make sure that any proposed explanations do not ignore the elementary facts of physics.

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