

# Grounding Plosive Place Features in Perceptuo-Motor Substance

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As early as 1928, the first typologies of phonological systems of the world's languages proposed by Troubetzkoy (1939) revealed that languages make use of relatively limited choices among all the phoneme possibilities determined by a simple combinatory rule. Thus, there is a strong bias in favor of systems with 5 vowels and 22 consonants. The most frequent consonant systems contain at least six plosives /p t k b d g/. If a language has three plosives (as in 3% of UPSID451 languages, e.g., Ainu, Maasai, Nicobarese, Yagua), it has /p t k/, rather than other combinations of place or a combination of place and secondary articulation contrasts (e.g., /p th kw/). If a language has six plosives, which is the most frequent number (in 24% of the languages of UPSID451), it has /p t k b d g/, rather than /p t c k q //, /b d g ! //, or /p nt ch k! qw //. With 9 plosives, the basic /p t k b d g/ series combines with secondary feature sets such as aspiration, prenasalization, palatalization or laryngealization (see for details Maddieson 1986b: 116–120). Altogether, in the UPSID extension to 556 languages (Maddieson 2001), 45% of the systems include the 6 plosives /p t k b d g/.

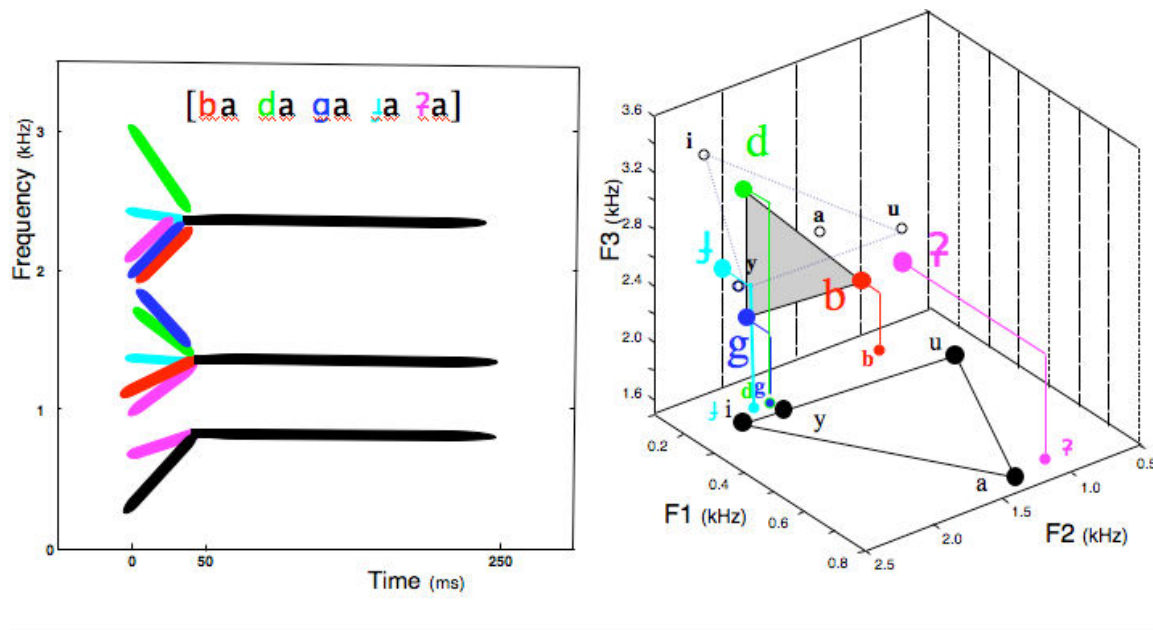
The three *bilabial*, *coronal* and *velar* places are thus omnipresent whereas the *palatal* (71 languages, 15.7% in UPSID) and *uvular* (62 languages, 13.7%) places are less frequently observed; the *pharyngeal* (or *epiglottopharyngeal*), observed and described (Elgendy, 2001; Maddieson, Wright, 1995), only appears in 3 languages in UPSID (0.7% with Bats and Avar, two caucasian languages and Iraqw, an afro-asiatic language). From *Preliminaries to Speech Analysis* (Jakobson, Fant, Halle, 1952), to *Acoustic Phonetics* (Stevens, 1998) [b d g] places have been associated with the three universal vowels /i a u/ as a triangle with binary contrasts: [g] being [+compact] vs. others [+diffuse], [b] [+grave] and [d] [+acute]. However, the acoustic vowel space associated to plosives in the [a ], [i ], [u ] context does not display [b d g] as extreme configurations for two reasons. Firstly, the vowel influence is very large, because of coarticulation. Secondly, the pharyngeal plosive [ʔ] provides a strong candidate in terms of maximal distance, rather than the other competing plosive places, particularly rather than [b] in the [a] context (Berrah *et al.*, 1995).

Recently Abry (2003) proposed to revisit the question of the perceptual optimality of [b d g] in the context of the *Frame then Content* (FC) theory (MacNeilage, Davis, 1990, 1998):

« In speech development, F1 is the audio movement corresponding to the carrier of speech, the mandibula, with labial [bababa] or coronal [dadada] "frames" [...] Whereas F2-F3 stream carries the information on places of contact, when independence of carried articulators (lip and tongue) from the jaw becomes settled. [...] When coarticulation emerges, after one year, the [a] vowel can now be produced during the closure phase, before opening, i.e. vocalic F1 is coproduced. Up to 4 years the mastering of the control of the whole vocal tract for [i] and [u] vowels will be in progress, if, like almost all languages, the mother tongue gets them. The differentiation process is thus comparable within the final two streams, F1-F2 mainly for universal [i]-[a]-[u] vowels, and F2-F3 for universal [b]-[d]-[g] consonants ».

Abry thus suggested that the consonantal acoustic triangle [b d g] in the F2–F3 plane is indeed acoustically optimally dispersed, provided that it is resituated in the developmental course of the FC theory, that is restricting the acoustic space to the consonants provided by jaw raising in the [a] context. The objective of the present paper is to reinforce Abry's proposals by providing articulatory-acoustic simulations of his predictions, thanks to a generic model of speech production (derived from Boë, Maeda, 1998). With this model: (i) we propose, in the [a] context, articulatory prototypes for [b d g " ʔ], together with the corresponding acoustic transitions; (ii) we verify that in this context, *coronal*, *velar* and *pharyngeal* places realize the maximal acoustic contrast; (iii) we show that when the jawraising principles of the FC theory are applied, [b d g] do appear as the solution of an auditory optimality problem for close configurations (rather than [d g " ʔ], since the pharyngeal plosive cannot be produced during the closure phase), which provides a substance-based explanation of their frequency in human languages, just as [a i u] are

solutions of an auditory optimality problem for open configurations. Altogether, an auditory dispersion principle combined with a natural unfolding of speech gestures within development (FC) provides a global solution for vowels, plosives and their combinations within syllables: the perceptuo-motor solution is part of the *Perception-for-Action-Control Theory* (PACT) that we have proposed for the explanation of phonological systems (Schwartz *et al.*, 2002, 2007).



Schematic representations of the [ba da ga ja ?a] syllables

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