Constraints, affordances, biases: the gentle influence of between-populations variation in vocal tract anatomy on sound change

Dan Dediu[1,*], Scott R. Moisik[2,1] and Rick Janssen[1]

[1] Language and Genetics, Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands

[2] Linguistics and Multilingual Studies, Nanyang Technological University, Singapore

[*] Corresponding author: Dan.Dediu@mpi.nl

Sound change is one of the most fascinating aspects of language and, despite continuous advance on several fronts, it remains somewhat of a mystery. The last decade has witnessed a resurgence in interest in the potential role played by extra-linguistic factors, such as climate, ecology, demography, and the biology of the speakers, in explaining the emergence and maintenance of the observed patterns of linguistic diversity (for two recent reviews please see (Dediu, Janssen, & Moisik, 2016; Lupyan & Dale, 2016)). The fundamental ideas, in a nutshell, are that such factors (a) differ between (some) linguistic communities, (b) are stable enough (on the timescales required for language change to take place), and (c) can act on language by changing the relative probabilities of a set of linguistic variants. It seems that most such factors exert very small effects that can, nevertheless, be amplified by the repeated language use and transmission in the right socio-linguistic circumstances, leading to cross-linguistic effects that are much stronger than would be predicted from the strength of the biases at the individual level (Dediu & Ladd, 2007; Kirby, Cornish, & Smith, 2008; Levinson & Dediu, 2013; Thompson, Kirby, & Smith, 2016).

Here we would like to focus on the biology of the language users as a source of biases potentially affecting language change and, thus, the emergence and maintenance of aspects of linguistic diversity. As argued elsewhere (Dediu, 2015; Dediu et al., 2016), on a background of comparatively high homogeneity due to our relatively recent origins and expansion across the world (Barbujani & Colonna, 2010; Jobling, Hollox, Hurles, Kivisild, & Tyler-Smith, 2013), there is extensive inter-individual and inter-population variation in almost all aspects of interest, ranging from the molecular to the cognitive. Importantly, this variation is gradual and continuous (i.e., there are no clear-cut boundaries that separate "crisp" groups from each other), and tends to be mostly distributed between the members of the same group rather than between groups (an often cited figure being about 80% to 20%), clearly going against any racist views of human diversity but, at the same time, also failing to support claims that variation does not exist or, if it does, that must be irrelevant. The anatomy of the vocal tract is no exception and biological anthropologists, medical practitioners, and phoneticians have documented intriguing patterns of inter-individual and between-groups variation.

Zooming on inter-individual variation, its extremes are most often pathologies that can affect speech production (e.g., cleft palate), but the range of normal variation may result in inter-individual differences in speech as well (Brunner, Fuchs, & Perrier, 2009; Tiede, Gracco, Shiller, Espy- Wilson, & Boyce, 2005). Such normal variants are sometimes distributed unequally between groups, resulting in statistical differences in what concerns their occurrence, and potentially result in slightly different forces affecting language change in different populations. To make things less abstract, we will illustrate these ideas with the case of click consonants that we have investigated using a variety of methods (Dediu, Moisik, & Levinson, in preparation; Moisik & Dediu, accepted, 2015). An old observation going back to Tony Traill (Traill, 1985), that we have supported with an extensive review of the literature (Dediu et al., in preparation; Moisik & Dediu, accepted), is that click-language speaking populations of southern Africa tend to have a reduced (or even "lacking") an alveolar ridge prominence (ARP), leading to the speculation that this may somehow be related to the occurrence of clicks in these languages' phonological inventory (Engstrand, 1997; Traunmüller, 2003). Using realistic bio-mechanical modeling, we have quantified this proposal and have shown that, indeed, a smaller ARP seem to reduce the muscle effort required for the articulation of a generic lingual click and may also enhance its acoustic properties (Moisik & Dediu, accepted). Moreover, in a large sample of participants trained in a standardized way to produce dental and (post-)alveolar clicks, we have shown, using structural and real-time MRI and intra-oral 3D optical scanning, that a smaller ARP seems to

increase the probability of correctly producing a (post-)alveolar click but not of a dental click (Dediu et al., in preparation). Taken together, these findings seem to suggest that (a) there is quite extensive inter-individual variation in the anatomy of the anterior hard palate (and of the ARP in particular), (b) that a subset of this variation may impact (post-)alveolar click production (apparently facilitated by a smaller ARP), and (c) that the speakers of some of the languages that include click consonants in their inventory tend to have the click-favoring anatomical configurations (a smaller ARP) when compared to other human groups.

Of course, our findings must be taken as preliminary and in need of replication and extension, but they do illustrate several important points and questions worth dwelling on here:

- How does individual anatomy affect articulation? Our view is that, while most variation in the anatomy of the language learners and/or users is effectively hidden by various compensatory mechanisms, some may still produce articulatory and acoustic effects (i.e., decrease the effort required for click production), generating (usually very weak) constraints or affordances (i.e., biases).
- How can such individual-level biases influence the community-level language? This is a well-known problem in language change, and we think that more modeling and experimental work must be done exploring communicative networks with heterogeneous nodes (i.e., where the individuals vary in their stable biases). A simpler version of this question concerns the proportion of biased speakers in a community necessary for language to start reflecting the bias, but a more realistic approach must consider also the structural properties of the communicative network and of these biased nodes (i.e., probably biased nodes with high centrality would have a higher chance of biasing the whole language).
- Are there detectable difference between "push" and "pull" biases (constraints vs. affordances) at the level of ongoing or realized language change? Our work on clicks suggests that there is a strong universal resistance against their incorporation in phonological systems despite their widespread cross-linguistic occurrence para-linguistically and as epiphenomena of speech production. This resistance may be relaxed by a reduced ARP and allows, as it were, normal sound change to do its work and result (sometimes) in the phonologisation of clicks.
- How relevant are such anatomical biases for sound change in general? Are clicks the only isolated case or is this a more general phenomenon? While we cannot currently answer these questions, we are developing computational, statistical and experimental methods (Dediu, 2011; Dediu & Moisik, 2016; Dediu et al., in preparation; Janssen, Moisik, & Dediu, in revision; Moisik & Dediu, accepted) that should allow the principled exploration of potential cases of biasing and of the conditions required for their amplification to cross-linguistic patterns of diversity.

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