CROSS-LINGUISTIC EVIDENCE FOR DEPENDENCE BETWEEN THE PERCEPTUAL DISPERSION AND SALIENCE OF VOWEL SYSTEMS

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Investigating typological variations of languages worldwide and generalizing their universality is an important research goal in linguistics. In general, the evolution of spoken language is carried out toward the functional goal of improving communicative effectiveness between speakers and listeners. During this process, several functional pressures from perceptual dispersion (Liljencrants and Lindblom, 1972), perceptual salience (Schwartz et al., 2007), and articulatory costs (Evans & Levinson, 2009; Hammarström, 2016; Chirkova & Gong, 2014) have been proposed as the intrinsic driving forces to lead to the universal patterns of sound systems of human speech, especially vowel systems. Following the principle of clarity (Zuidema & de Boer, 2006), the dispersion theory states that the sound systems of human speech are shaped predominantly by perceptual distinctiveness between sounds (Liljencrants and Lindblom, 1972). Moreover, the dispersion-focalization theory integrates both perceptual dispersion and salience of vowels to investigate the general formation mechanism underlying the global structural variation of vowel systems (Schwartz et al., 2007). Moreover, both perceptual dispersion and salience of vowels can be measured based on the formant frequencies of vowels which are related to the tongue movements and

opening/closing of the jaw (Oudeyer, 2006; Bradlow, 1995). In addition, the Quantal theory (Stevens, 1972) and the articulatory complexity theory (Lindblom & Maddieson, 2006; Kingston, 2007) characterize articulatory difficulty in speech production where the auditory pressures of maximizing perceptual distance and minimizing articulatory effort cohesively shape the articulatory subspace of a sound system.

Despite these theories being proposed independently, they imply the association between perceptual dispersion and salience under articulatory effort minimization. In this study, we conduct a cross-linguistic comparison using a worldwide phonetic database (Becker-Kristal, 2010). The database contains formant frequencies of each vowel for 532 individual samples covering 357 languages from 36 language families. We adopt two properties named Effective Dispersion estimate (EDE) and Focalization estimate (FE) to capture the structural crowdedness of a vowel system and the spectral salience of intra-vowel sounds, respectively. EDE is specifically a composite property of the classic Dispersion estimate divided by articulatory space area. All properties are calculated on the psychoacoustic domain.

Using a linear mixed effects model (Quené & Bergh, 2008), we identify that the association between perceptual dispersion and salience follows a power-law-based dependence across vowel systems of worldwide languages. We also demonstrate that such dependence was a language-universal tendency, independent of geographic regions, language families, and linguistic affiliations. Using the phylogenetic methods such as PIC (Felsenstein, 1985; Paradis, 2012) and PGLS (Paradis, 2012), we take Indo-European languages as an example to elaborate that the dependence resulted from correlated evolutions of the two structural properties. The results show the correlated evolution could follow an adaptation process under the stabilizing selection pressures. These results also indicate that the evolution of vowel systems could be a dynamic process of adaptive organization of their structures and optimization capacities. The phylogenetic analysis also shows that the dependence should proceed in a punctuated equilibrium. In other words, the correlated evolution of EDE and FE is not a gradual process. It suggests an evolution scenario: vowel systems tend to slowly accumulate structural changes till reaching a threshold, and then, the whole system is rapidly restructured. To extend the scope of early explanations of language universals, we provide our understanding of these findings from four aspects: language change dynamics, self-organizing criticality of system complexity, and the principle of the least effort in human behavior.

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