

A probabilistic typology of Proto-Indo-European stops

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The traditional reconstruction of Proto-Indo-European (PIE) has a three-way stop contrast consisting of voiceless (T), voiced (D) and voiced-aspirated (Dh) stops (e.g., Clackson, 2007). This stop system, T-D-Dh, which excludes the voiceless aspirates (Th) is typologically exceedingly rare, if not entirely unattested. I present a direct test, based on typological evidence, of the plausibility of different PIE inventories in a probabilistic implementation of Optimality Theory (OT). I show that the most likely candidate for the synchronic PIE inventory is the four-way system, T-Th-D-Dh.

To assess how well a certain PIE inventory predicts the observed typology of modern Indo-European (IE) languages, a model couched in Maximum Entropy Harmonic Grammar (Goldwater and Johnson, 2003; Hayes and Wilson, 2008), or Max-Ent, a probabilistic version of OT (Prince and Smolensky, 2004), is used. It takes a potential PIE inventory as an input and predicts probability distributions over candidate inventories, given a set of constraints. Considering labials, denti-alveolars and velars as possible places of articulation which can co-occur with one of six possible laryngeal settings – constricted (Tc) and voiced-constricted (Dc), in addition to T, Th, D and Dh – the maximal stop inventory is assumed to contain 18 stops, yielding a total of 2^{18} possible inventories.

To capture general typological tendencies that shape inventories, a Max-Ent model was first trained on all except the IE inventories in PHOIBLE (Moran and McCloy, 2019), using `maxent.ot` (Mayer et al., 2024). This model had no input (Flemming, 2013) and predicted the prevalence of attested inventories as well as unattested inventories, randomly sampled from the remaining 2^{18} inventories. Constraints were specified that (1) maximized the distinctiveness of contrasts (2) minimized articulatory effort, and (3) maximized the number of contrasts (Flemming, 2013). The weights learned by this model, which were assumed to be representative of universal underlying tendencies influencing the makeup of all stop inventories, were assigned as priors to the model simulating IE stop typology. In this model the candidates were inventories of all the IE languages in PHOIBLE, as well as non-IE languages, and unattested languages. A successful model would correctly assign high probabilities to common IE inventories and low probabilities to non-IE and unattested inventories. In addition to constraints (1)-(3), *MAP constraints (Zuraw, 2007, 2013) penalized changes in the output inventories relative to the PIE input.

Results from the models (Table 1) showed that

Model1, that is, the four-way system as the input, best predicted the attested IE stop typology. This suggests that, from a typological standpoint, the traditional reconstruction of PIE stops as T-D-Dh (*Model2*) is unlikely to have been its synchronic inventory. Instead, the typologically well-attested and stable system in *Model1* (T-Th-D-Dh) is the most plausible candidate for the synchronic PIE stop inventory, consistent with proposals such as Elbourne’s (1998). The traditional reconstruction, however, is more likely than the proposal of the glottalic theory (*Model3*) (Gamkrelidze and Ivanov, 1995; Hopper, 1973), despite the latter being typologically attested and stable. In addition to providing a rigorous test of older claims, this study demonstrates the use of well-motivated typological principles within a widely used phonological framework to assess the plausibility of historical reconstructions.

Model	Inventory	BIC
Model1	T-Th-D-Dh	1215.58
Model2	T-D-Dh	1261.30
Model3	T-Tc-D	1281.33

Table 1: Model Results. Lower BICs indicate better fit.