Mapping Features to Cues:
A Neural Network proposal for laryngeal stops in Seoul Korean

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Phonological features are expected to be able to **contrast** between different phonemes, **describe** phonological processes, and to be **phonetically interpretable**. Here we discuss how phonetic interpretability falls short when using theories that posit a universal feature system, where there is one unchangeable main phonetic cue per feature. We suggest that Seoul Korean (SK) may benefit from allowing one feature to accept multiple phonetic cues, which are also position-dependent. We put forward BiPhon (Boersma 2007, 2011) as a possible formalization.

SK has an uncommon three-way laryngeal contrast for plosives in which all three are voiceless in word- and phrase-initial position. Two phonological processes have been established relating to this laryngeal contrast; post-obstruent tensification (POT) and coda neutralisation:

- POT: a lenis stop is realised as fortis, when in post-obstruent position.
- Coda neutralisation: fortis and aspirated stops are realised as lenis in coda position.

The following privative features proposed by Lombardi (1994) can account for these processes:

	Lenis	Fortis	Aspirated
[Spread glottis]			✓
[Constricted Glottis]		✓	

Table 1: The phonological analyses by Lombardi (1994), adapted from Kang et al. (2022)

In POT, lenis gains the feature [cg] since it is unmarked, whereas aspirated cannot gain the feature as it is already [sg]. In coda neutralisation, both fortis and aspirated stops lose their respective features to become unmarked, while lenis remains as is. Although this describes the two phonological processes well, and also contrasts between three phoneme sets, phonetical interpretability is still an issue. Phonetic research has demonstrated that the contrast is distinguished by F0 enhancement in aspirated stops, with VOT increasingly becoming redundant between lenis and aspirated, and fortis being contrasted through a short VOT (c.f. Bang et al. 2018 for an overview). However, other cues also appear to be relevant, and appear to be strongly affected by prosodic position (e.g., Jun 2020), see Table 2.

	Aspirated	Fortis	Lenis
Phrase-initial	Highest F0 Long-Mid VOT Modal/breathy	High F0 Shortest VOT Modal / creaky	Mid-low F0 Mid VOT Breathy/modal
Non-phrase initial	High F0 (lowered) Longer VOT Breathy / modal	High F0 Short-mid VOT Modal / creaky	Mid F0 Mid-long VOT Modal, can be voiced

Table 2: Slightly simplified overview of phonetic cues in phrase-initial and phrase-internal, word-initial position.

The above presents a challenge for theories that assume one consistent cue for each phonological feature, including Lombardi (1994): the lenis stop does not contain one universal phonetic cue, but can operate in a gradient manner highly dependent upon prosodic position, with seemingly multiple cues interacting at once to create a lenis realisation. Although privative systems are better than binary, as they allow for lenis to be unspecified, they still do not fully account for the fact that multiple phonetic cues can be employed to determine a phonological contrast (see, e.g., Nearey 1995 for multiple mappings; and Cho et al. 2002 for phonetic results and implications in SK).

For a formalization of this multiple mapping between phonetic realization and phonological specification, we propose the BiPhon model in the form of a symbolic neural network, given in Fig.1, where each phonological feature (top layer) maps onto several phonetic cues (bottom layer), and vice versa. This network can account for the perception and production of all three laryngeal contrasts in two positions, at the boundary of an Accentual Phrase (AP) and within, as expressed with the left-most top node "within AP" that can be activated or not. The two illustrations below show the perception of lenis stops at an AP boundary (left) and within an AP (right). In perception, only the relevant bottom nodes, the perceptual cues as specified in Table 2, are activated initially (the periodicity node on the left bottom represents voicing during closure as occuring forlenis within an AP). Activation then spreads along the connections and activates (depending on the connection strengths) top nodes. As we can read off from the top nodes in this example, the network correctly "perceives" the phonetic input corresponding to a lenis as a lenis phonological category (though the feature specification [spread] is also partially activated, as triggered by the cues of breathiness in the vowel and mid and mid-long VOT).

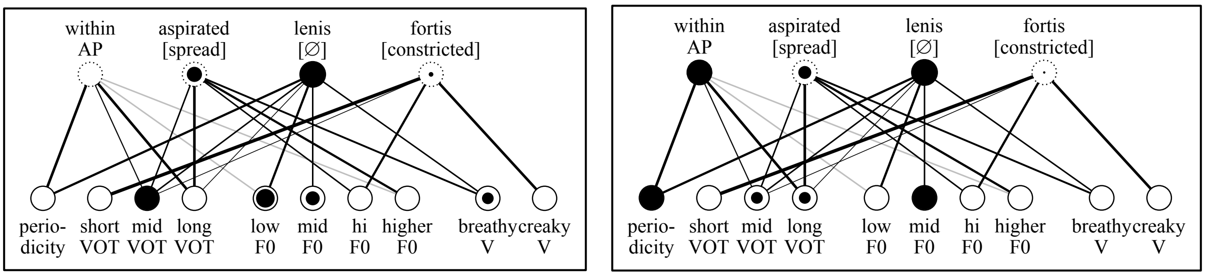

Figure 1: Lenis perception AP-initial (left) (behaviour as in phrase-initial position: Jun 1995) and within an AP (right)

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