Harmony versus Distance in Phonetic Enhancement.

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Most languages contrast rounded back vowels with unrounded front vowels. This correlation of backing and rounding is the prototypical case of 'Phonetic Enhancement'(PE), whereby features that have similar acoustic correlates combine rather than varying independently (Stevens, Keyser and Kawasaki 1986). Rounding and backing have similar acoustics by way of a lower F2 resulting from a longer front cavity. PE is thought to occur to satisfy a desideratum on the communicative process – greater perceptual distances between phonemes or 'Dispersion' (Lindblom 1986, Flemming 1995, 2004, de Boer 2001).

We present a novel interpretation of PE, based on maximization of harmony in a neural network (Smolensky 1986) rather than perceptual distance. Our approach derives from the 'Representational Entailments Hypothesis' (REH) of Burzio (2002a, b), (2005), which states that in a complex mental representation, each component entails each of the others. Such hypothesis is analogous to a system of distributed representations using the connectivity of a Hopfield (1982) neural net, in which all units are interconnected. When trained -for example- on a vector A, -B, C, a Hopfield net will acquire the weight matrix shown in Fig. 1, where each of the weights is the analog of one entailment within the REH (A entails A; A entails -B; etc.). Under the REH or its Hopfield implementation each representation behaves as an attractor, able to influence other representations via the entailments/ harmony gradient it produces. Burzio motivates such a proposal based on evidence from a broad range of effects in Phonology and Morphology, from segmental neutralizations and assimilations, to Paradigm Uniformity, to morphological syncretisms suggesting that such effects are best understood as types of attraction. Burzio (2005, 77-81) claims that in addition to attraction the REH also predicts as a further corollary that two components of a representation, while generally entailing one another as in Fig.1, will do so more robustly if they are similar, an effect that will tend to bind them together into a cluster, precisely as in the case of PE. The reasons behind this expectation receive an intuitive characterization with the help of Fig.2. We characterize similarity of components as identity of subcomponents, so that when some A and B are similar some subcomponent of A, a_i will equal some subcomponent of B, b_j. In that case, an entailment $a_1 \Rightarrow a_i$ (a_1 entails a_i) due to the internal structure of A will also be an entailment from A to B, $a_1 \Rightarrow b_j$, thus strengthening the association of A and B.

The paper reports on a Hopfield net simulation that proves this binding corollary, thus showing that PE is subsumed under the REH. The three features [± back], [± round], [± high] were decomposed into their acoustic subcomponents reflecting their respective contributions to F1 and F2. The Hopfield net simulation then tested the interaction of the non-orthogonal combination [± back], [± round] and compared it with that of the orthogonal combination [± back], [± high], yielding the results of Figures 3 and 4, respectively. While the network received equal training on all points in each case, in the first case (Fig.3) greater harmony peaks/ attractors developed at the PE points, corresponding to [i] and [u] for the high vowels. In the second case (Fig. 4), however, equal harmony peaks developed in all four corners. This behavior shows that, in addition to PE, the REH also yields 'Dispersion'. These results are significant for two main reasons: I.The REH is motivated by a broad range of evidence that goes beyond phonetics, and thus provides a more general solution to PE than one based on perceptual distance alone. It also predicts binding effects at higher level of granularity, with the potential for shedding light on the typology of morphemes just as PE sheds light on the typology of phonemes. II. The solution based on harmony maximization appears to overcome a flaw that has plagued the distance-based theory from the beginning and noted in Ohala (1980). Distance would be enhanced by clustering of features even when these are orthogonal, as in the 'diagonal' vowel inventory of Fig. 5, which, however, is not attested, in contrast to the 'vertical' one of Fig. 6, which is. By contrast, while still yielding Dispersion, the present system produces a diagonal configuration *only* when features are non orthogonal, as in Fig. 3. In order to privilege one diagonal in the conditions of Fig. 4, the system would have to overcome the effects of uniform training *as if* it were 'planning' for maximal distance. The brain, we contend, makes no such plan, however.

	A	B	C
A	1	-1	1
B	-1	1	-1
C	1	-1	1

Fig. 1. Weight Matrix for Vector A, -B, C

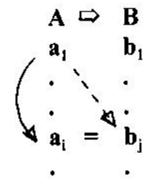


Fig. 2. Entailments under Similarity

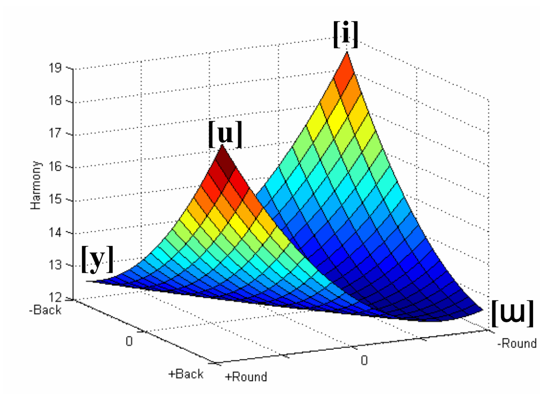


Fig. 3. Interaction of [back] and [round]

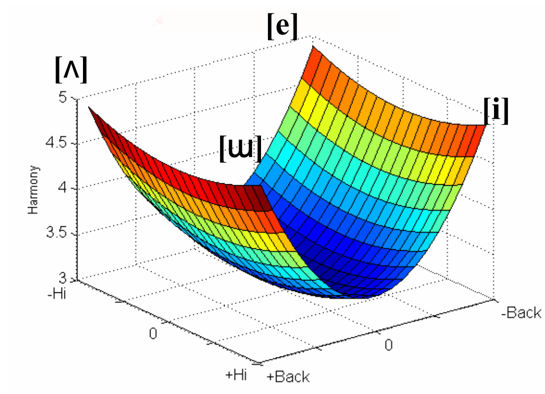


Fig. 4. Interaction of [back] and [high]

Fig. 5. Diagonal vowel inventory

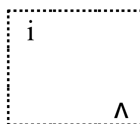
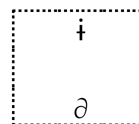


Fig. 6. Vertical vowel inventory



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