Neighborhood density and minimal pair effects on English pre-voicing vowel duration

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It is well-established that lexical competition conditions variation in phonetic realization. Some work has focused on neighborhood density (ND), finding that speakers produce words with many similar-sounding neighbors with hyperarticulated vowels [1]. Other work suggests that specific neighbors—namely, the existence of particular minimal pairs, rather than overall ND—can condition *contrastive* hyperarticulation. For example, words with voiceless-initial stops (e.g., *cod*) that have voiced-initial competitors (e.g., *god*) have longer voice onset times (VOTs) than those without such competitors (e.g., *cop*, which does not have competitor **gop*) [2]. On the other hand, [3] argue that it is ND (rather than the existence of a specific minimal pair) that is correlated with VOT. This present study looks at coda voicing–conditioned vowel duration in English to examine the effects of both ND and minimal pairhood on a *secondary* cue. In English, vowels before voiced consonants are longer than vowels before voiceless consonants. This study's results suggest that while vowel duration is not phonemic in English, it is subject to contrastive hyperarticulation and that both ND and minimal pairhood play a role in explaining vowel duration variation.

Participants ($n = 20$) read 100 words, distributed across minimal pair (MP) and non-minimal pair (NMP) and coda voicing categories, as shown in Figure 1. The wordlist was divided into ten randomized blocks of ten ordered words. MP words were presented as pairs, one after the other, within blocks. The order of coda voicing within pairs was counter-balanced. While blocks were randomized, words within the blocks were always in the same order. The MP words that came first in the pair were coded as MP1; words that came second in the pair were coded as MP2. All NMP words were coded as NMP. Linear mixed effects regressions and model comparison tests were performed to assess the explanatory power of MP type (MP1/MP2/NMP) and ND on vowel durations. ND values were taken from CLEARPOND. All linear mixed effects regression models included a speaker random effect.

The MINIMAL PAIR TYPE MODEL included simple effects of coda voicing, MP type, and their interaction. With MP1 as reference level, there was a significant interaction between coda voicing and MP type for MP2 (est. = -0.015, $t = -2.452$, $p = 0.014$). This indicates that for voiceless coda words, MP2 exhibits vowel shortening relative to MP1 while for voiced coda words, MP2 exhibits vowel lengthening relative to MP1 (Figure 2). This is interpreted as contrastive hyperarticulation of vowel durations in words produced immediately after their minimal pair competitor.

The NEIGHBORHOOD DENSITY MODEL included simple effects of coda voicing, ND (as a continuous variable), and their interaction. There was a significant interaction between ND and coda voicing (est. = -0.001847, $t = -8.382$, $p < 2 \times 10^{-16}$), indicating that vowels are shorter in voiceless coda words with higher ND. This is interpreted as voicing-conditioned hyperarticulation of vowel durations in high-ND words: shorter vowels in voiceless-coda words and longer vowels in voiced-coda words (Figure 3).

While these models showed explanatory power for both MP and ND, Akaike Information Criterion (AIC) values compared the goodness-of-fit of the two models. Lower AIC values indicate a better fit. The ND MODEL (AIC = -6328.53) thus appears to fit the data better than the MP TYPE MODEL (AIC = -6253.93).

However, it is also possible that both MP type and ND play a role, interacting to account for vowel durations. To examine this possibility, a third model examining the interaction of ND and MP type (along with coda voicing) was run. The NEIGHBORHOOD DENSITY * MINIMAL PAIR TYPE MODEL included simple effects of coda voicing, ND, MP type, and their interactions. With MP1 as reference level, this model indicates significant three-way interactions for both MP2 (est. = -1.51×10^{-3}, $t = -2.639$, $p = 0.0084$) and NMP (est. = -2.553×10^{-3}, $t = -4.609$, $p = 4.31 \times 10^{-6}$). See Figure 4. Compared to MP1, both MP2 and NMP show a greater coda voicing–conditioned vowel duration difference in high ND words. However, the model also suggests a crucial way in which MP and NMP words differ: low-ND words. As illustrated in Figure 4, even in low-ND contexts, MP1 words display coda voicing–conditioned vowel duration differences whereas NMP vowel durations are similar regardless of coda voicing. MP2 words also appear to show coda voicing–conditioned vowel duration differences in low ND contexts. This is interpreted as speakers hyperarticulating voicing-conditioned vowel duration differences even in low ND contexts when a MP competitor exists. In this way, minimal pairhood may mediate the effects of ND.

Likelihood ratio tests (LRTs) compared the goodness-of-fit of the ND * MP TYPE MODEL to the previous two simpler models. In both LRTs, χ^2 values indicated a better fit for the ND * MP TYPE MODEL (vs. MP TYPE MODEL $\chi^2 = 98.017$, $p = 2.2\times10^{-16}$; vs. ND MODEL $p = 33.529$, $\chi^2 = 4.945\times10^{-5}$).

Taken together, these findings suggest several key takeaways: (1) vowel duration, while not phonemic in English, is contrastively hyperarticulated in certain minimal pair conditions; (2) voicing-conditioned vowel duration is also influenced by neighborhood density, with longer or shorter vowel durations, depending on the coda voicing, in high ND words; and (3) minimal pairhood mediates ND effects, especially in low density contexts.

	voiced coda	voiceless coda
MP	e.g., *pod* (n = 25)	e.g., *pot* (n = 25)
NMP	e.g., *fed* (n = 25)	e.g., *vet* (n = 25)

Figure 1.

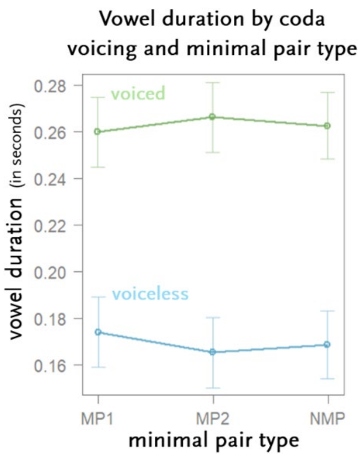

Figure 2.

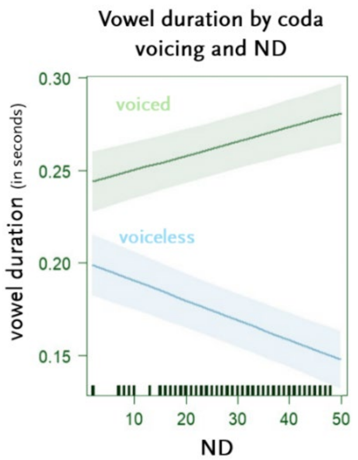

Figure 3.

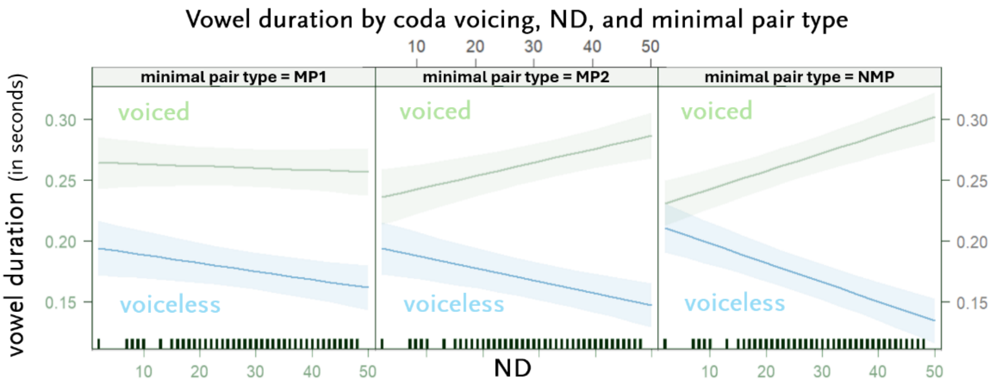

Figure 4.

[1] Munson, B., & Solomon, N. P. (2004). The effect of phonological neighborhood density on vowel articulation. *JSLHR*, *47*(5), 1048-1058.
[2] Baese-Berk, M., & Goldrick, M. (2009). Mechanisms of interaction in speech production. *Language and cognitive processes*, *24*(4), 527-554.
[3] Fox, N. P., Reilly, M., & Blumstein, S. E. (2015). Phonological neighborhood competition affects spoken word production irrespective of sentential context. *JML*, *83*, 97-117.