Effects of following voicing on perceived vowel duration

Chelsea Sanker, *Brown University* (chelsea_sanker@brown.edu)

Introduction: Vowels are longer before voiced consonants than voiceless consonants in English and many other languages. Various explanations have been proposed (e.g. Chen 1970, Kluender et al. 1988), but the underlying cause remains in question. Port & Dalby (1982), among others, have demonstrated that this difference in vowel duration is a perceptual cue for coda voicing, illustrating some of the flexibility of redundant cues for the same contrast.

I present two perceptual studies on how coda consonant voicing affects perception of preceding vowel duration. Voiceless codas create a bias towards categorizing vowels as long, suggesting compensation for environmentally conditioned lengthening. However, the acoustic effects of voiceless codas, when the coda itself is removed, create a bias towards categorizing vowels as short, suggesting a possible perceptual origin of voice-induced duration differences.

Methods: Study 1: 20 English speakers heard VC nonce words with voiced and voiceless stop codas and categorized the vowel of each item as being 'long' or 'short' in duration. Items were split into blocks based on vowel quality (/ɑ/, /i/, /u/). Vowel duration was manipulated to create stimuli covering a 10-step duration continuum (129 ms to 252 ms).

Study 2: 15 English speakers heard isolated vowels that came from VC productions with the consonant and the transition into it completely removed; half of stimuli were produced with voiced stops and the other half were produced with voiceless stops. The stimuli (vowel qualities and durations) and procedure were otherwise the same as Study 1.

Results: Listeners were able to perceive and categorize vowel duration. In both studies, the duration of the vowel was a major predictor of whether it was identified as 'long' or 'short'; this is illustrated in Figures 1 and 2, as well as the mixed effect models in Tables 1 and 2.

Coda voicing was a significant predictor of responses. When the original coda was present (Study 1), listeners gave more responses of 'long' when that coda was voiceless (Figure 1; Table 1). This follows from knowledge of English phonology; shorter durations are expected in this environment, so listeners compensate in their threshold for 'long' vowels. A similar compensatory pattern was found for vowel qualities of different intrinsic duration.

When the coda was removed (Study 2), the pattern was reversed; listeners gave more responses of 'long' for vowels that had been produced before a voiced coda (Figure 2; Table 2). The vowels exhibit several acoustic characteristics influenced by voicing of following stops. Vowels produced before voiced stops have a lower F0, lower F1, higher harmonics-to-noise ratio, and less jitter. Some of these characteristics likely contribute to perceived duration, and may contribute to phonologized lengthening of vowels before voiced consonants.

Conclusions: Because vowels are longer before voiced consonants, vowel duration is used as a cue for coda voicing; mirroring this, codas can set expectations about vowel duration, with a higher threshold for short vowels before voiced codas. Other work has demonstrated that category boundaries shift to compensate for environmental effects (e.g. Mitterer 2006). The present study, in combination with previous work on stop identification, suggests that cue interaction is bidirectional, and the task influences which cue is used to inform the other.

The reversal of the voicing bias when codas are removed suggests a possible perceptual pathway that at least partially explains the duration effect of voicing. With phonologically driven biases removed, acoustic differences resulting from production of voiced and voiceless codas create differences in the perceived duration of vowels extracted from each environment.

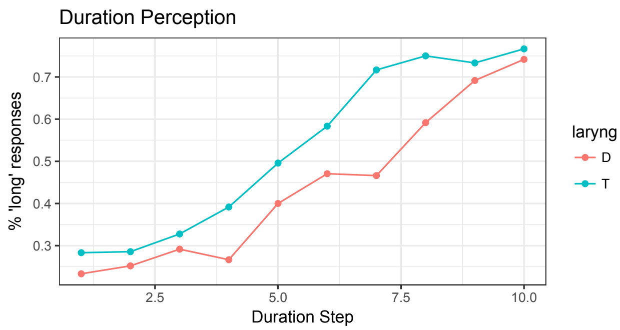

Figure 1: Study 1: 'long' responses, by coda voicing (D = voiced, T = voiceless)

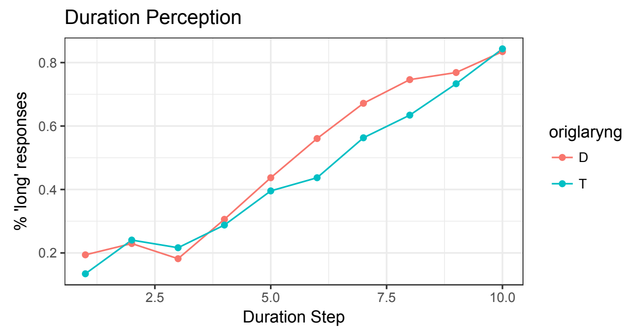

Figure 2: Study 2: 'long' responses, by original coda voicing (D = voiced, T = voiceless)

References:

Chen, M. (1970). Vowel length variation as a function of the voicing of the consonant environment. *Phonetica, 22)*, 129–159.

Kluender, K. R., Diehl, R. L., & Wright, B. A. (1988). Vowel-length differences before voiced and voiceless consonants: An auditory explanation. *Journal of Phonetics, 16*, 153–169.

Mitterer, H. (2006). On the causes of compensation for coarticulation: Evidence for phonological mediation. *Perception & Psychophysics, 68(7)*, 1227–1240.

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	Estimate	Std. Error	t value	p value
(Intercept)	-2.53	0.23	-10.8	< 0.0001***
DurationStep	0.31	0.018	17.5	< 0.0001***
CodaVoicing-Voiceless	0.49	0.094	5.17	< 0.0001***
Vowel-i	0.74	0.12	6.39	< 0.0001***
Vowel-u	0.78	0.12	6.73	< 0.0001***
ResponseTime	-0.0015	0.063	-0.024	0.98

Table 1: Generalized linear mixed effects model for 'long' responses in Study 1
Intercept: Voicing = Voiced, Vowel = a

	Estimate	Std. Error	t value	p value
(Intercept)	-2.27	0.22	-10.3	< 0.0001***
DurationStep	0.40	0.018	22.3	< 0.0001***
OrigCodaVoicing-Voiceless	-0.25	0.090	-2.74	0.0062**
Vowel-i	0.19	0.11	1.75	0.079
Vowel-u	-0.061	0.11	-0.55	0.58
ResponseTime	0.00097	0.085	0.011	0.99

Table 2: Generalized linear mixed effects model for 'long' responses in Study 2
Intercept: Voicing = Voiced, Vowel = a