

Formant Characteristics of Unstressed Unreduced Vowels in American English: Only Explained by Duration?

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科研費
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Four Levels of English Vowels

- P** (Primarily Stressed) *'au diences*
- S** (Secondarily Stressed) *'au di'toria*
- U** (Unstressed Unreduced) *au' dition*
- R** (Unstressed Reduced) *a/ə/' ddition*

Fear et al. (1995)

Production Experiment

- Duration: R < U < P/S
- Vowel quality: R < U < P/S
(“X < Y” = X is more reduced than Y)

Perception Experiment

P, S, U, R ⇒ cross-spliced ⇒ listeners rated the acceptability of words ⇒ U were more steadily grouped with the P/S rather than R.
(U is perceptually categorized as full vowels just as P/S are, despite their phonetic reduction.)

Question

Is U's phonetic reduction in vowel quality only a by-product of its shorter duration?

The Target Undershoot Model

Shorter vowel duration ⇒ more difficult for articulators to reach their targets ⇒ reduction in spectral characteristics (Lindblom 1963, Moon & Lindblom 1994).

The strongest hypothesis:

U is primarily associated with shorter duration than P/S, and the reduction in their vowel quality is nothing but a by-product of their shorter duration.

The alternative hypothesis:

U's articulatory target is set at a slightly slacker position than P's/S's independently of its shorter duration, and the U's vowel quality differs from P's/S's even after the effect of duration is removed.

Production Experiment

- 25 native AE speakers: 10 males, 15 females (undergraduate or graduate students at universities in the US: eight from New England, six from the West, five from the South, three from the Midland, one from the North Central area, one from the Inland North area. One was raised in multiple areas.)

Word Sets

Vowel Group 1: /æ/

- Set1 (P) 'active (U) ac'tivity
(S) 'acti'vation (R) a/ə/c'cept
- Set2 (P) 'asphalt (U) as'phaltic
(S) 'aspi'ration (R) a/ə/s'paragus

Vowel Group 2: /ɔ: ~ α:/

- Set3 (P) 'audiences (U) au' dition
(S) 'audi'toria (R) a/ə/' ddition
- Set4 (P) 'authorize (U) au'thentic
(S) 'authen'ticity (R) A/ə/' thena

Embedded in *What did you say? I said “___”*

Acoustic Measurements

For the initial vowels:

- **Duration** ⇒ logarithmic scale (Ln)
Normalized: Deviations from the mean (for each **Speaker*each Vowel Group**)
- **F1, F2 at midpoint** ⇒ Bark scale
Greater **F2-F1** = more reduction

Preliminary Observations

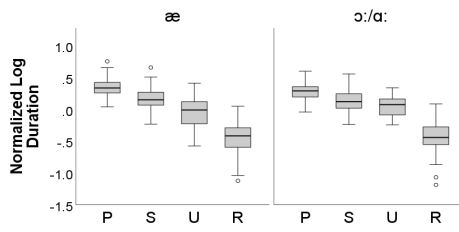


Figure 1. Normalized duration of the four levels

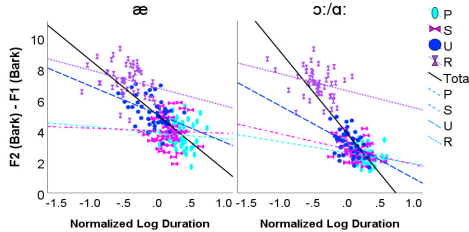


Figure 2. F2-F1 plotted against normalized duration

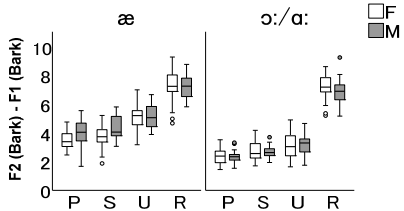


Figure 3. Normalisation between the two gender groups was achieved given the difference between F2 and F1.

Statistical Analyses

Linear Mixed Model was adopted to examine whether (i) and (ii) were the case:

- (i) F2-F1 differs between U and the other vowel types even when *Duration* is controlled for (i.e., even if *Duration* is kept constant),
- (ii) The slopes (i.e., the relationship between F2-F1 and *Duration*) are different between U and the other vowel types.

Target variable = F2-F1

For each Vowel Group, three models with the following fixed factors were compared.

Model 1: *Type* (i.e., P, S, U, R)

Model 2: *Type, Duration*

Model 3: *Type, Duration, Type*Duration*

Random intercepts of **Speaker** and those of **WordSet** were also included in the three models.

Acknowledgments

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Results

AIC (for both of the Vowel Groups):

Model 3 < Model 2 < Model 1

Table 1. Fixed Coefficients (Model 3) /æ/

	β	SE	t	95%CI	
Intercept (U)	5.1	.20	25.9***	4.7	5.5
difference (P-U)	-1.2	.29	-4.2***	-1.8	-.66
(S-U)	-1.1	.19	-6.0***	-1.5	-.77
(R-U)	1.7	.25	6.7***	1.2	2.2
Slope (U×D)	-1.6	.51	-3.2**	-2.6	-.60
difference (P×D-U×D)	1.2	.90	1.3	-.59	3.0
(S×D-U×D)	1.7	.85	2.0†	.05	3.4
(R×D-U×D)	.49	.69	.71	-.87	1.8

Table 2. Fixed Coefficients (Model 3) /ɔ: - α:/

	β	SE	t	95%CI	
Intercept (U)	3.3	.19	17.5***	2.9	3.7
difference (P-U)	-.57	.23	-2.5*	-1.0	-.12
(S-U)	-.51	.14	-3.5***	-.79	-.22
(R-U)	3.2	.21	15.8***	2.9	3.7
Slope (U×D)	-2.2	.60	-3.6***	-3.4	-.98
difference (P×D-U×D)	.99	.91	1.1	-.81	2.8
(S×D-U×D)	1.5	.84	1.8	-.16	3.2
(R×D-U×D)	1.0	.73	1.4	-.42	2.5

*** < .001, ** < .01, * < .025, † < .05

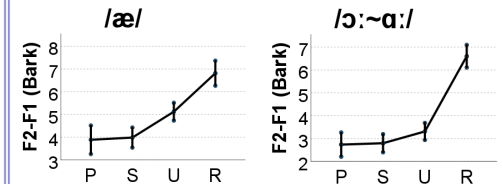


Figure 4. Estimated marginal means of F2-F1: the vowel duration fixed at 0 (= the durational mean)

Discussion and Conclusion

(i) Given the mean vowel duration, **F2-F1: P/S < U < R**

➔ U's phonetic reduction is not merely a by-product of its shorter duration.

Implication: U's articulatory target is set at a slightly slacker position than P's/S's.

(ii) Although U's slope is estimated to be different from the other vowel types' slopes, the difference was not statistically significant.

Additional Findings:

U's reduction is more pronounced for the lax vowel /æ/ than for the tense vowel /ɔ:~ α:/.

➔ Lax vowels have been claimed to be more prone to reduction than tense vowels in metrically weak position (Chomsky & Halle 1968).

➔ Is the “U” lax vowel /æ/ perceptually grouped with P/S, keeping its unreduced quality? A perception study is necessary.

Another Comment:

- Additional word sets with other vowels with/without onset consonants were also recorded in the production experiment. They will be considered in the future study.
- The target words were also recorded in a post-focus environment, and it is of interest how U vowels behave in that environment.

References

Fear, B. D., Cutler, A., Butterfield, S. 1995. The strong/weak syllable distinction in English. *J. Acoust. Soc. Am.* 97, 1893-1904.
Lindblom, B. 1963. Spectrographic Study of Vowel Reduction. *J. Acoust. Soc. Am.* 35, 1773-1781.
Moon S-J, Lindblom, S. 1994. Interaction between duration, context, and speaking
Chomsky, N., Halle, M. 1968. *The Sound Pattern of English*. MIT Press.