Phonetic Opacity:
Flapping and Vowel Length in American English

Aaron Braver*
Rutgers, The State University of New Jersey
abraver@rutgers.edu

RULING III
10 May, 2008

1 Introduction

(1) Big question: What leaves the phonological module?
  a. Morphological structure?
  b. What does the 'output' look like?

(2) Today's question: Does more than just the 'output' leave the module?
  a. How we'll get there: phonetic opacity

1.1 Two Types of Opacity

(3) Phonological opacity
  a. /a/ → [a′] / _ b
  b. /b/ → ∅ / _ c
  c. /abc/ → /a′bc/ → [a′c]

(4) I propose that there is a second type of opacity: "phonetic opacity"
  a. Phonetic Opacity: A phonetic process is opaque when it applies based on some context other than the phonological output (e.g. the phonological input)
  b. Hypothetical example: a phonetic process devoices nasals before a voiceless stop
    i. /pɪns/ → [pɪns] → ⟦pɪn̥s⟧[1]

*Thanks are due to the Spring 2008 Phonology II class at Rutgers for comments on a previous version of this talk, as well as to Jeremy Perkins for discussion of the interaction between flapping and Canadian raising. This presentation stems from previous work on the input to the phonetic module, which has benefited greatly from discussions with Will Bennett, Paul de Lacy, and Alan Prince. All errors are, of course, my own.

[1]Text inside ⟦double brackets⟧ represents actual phonetic realization

ii. Imagine a phonological process which deletes to prevent word-final clusters, *but* the /n/ is still devoiced *phonetically*

iii. /pɪns/ → [pɪn] → ⟦pɪn̥⟧

iv. (Underlying /pɪn/ surfaces as ⟦pɪn⟧)

(5) Flapping and pre-consonantal vowel length

a. English vowels lengthen before voiced stops (phonetic ?)

b. 'ride' /ɹaid/ → [ɹaid] → ⟦ɹaiːd⟧[2]

c. English also has intervocalic flapping of coronal stops, except before stressed syllables (phonological ?)

d. Flaps are always voiced, and therefore we expect them to trigger phonetic vowel lengthening whenever they precede a vowel

i. This should happen regardless of the voicing specification of the flap's input correspondent

(6) One way to explain phonetic opacity is by reexamining what information the phonetics has access to

a. Standard assumption: the phonetics has access to the *output* of a winning candidate

b. Proposed model: the phonetics has (limited) access to more parts of the winning candidate

i. Candidate: input, output, some record of changes between the two

2 The Standard Model

(7) Input → GEN → Cand A / Cand B / Cand C → Eval → { **Winner** a. /Input/ b. Record c. [Output] } → Phonetics

(8) Only the *output* of the winning candidate is accessible to the phonetics

a. Phonetic processes should only be able to be conditioned by the output

3 Phonetic or Phonological? Some Assumptions

3.1 Flapping is Phonological

(9) I will assume that flapping is a phonological process, not a phonetic one

[2] I use the IPA length diacritic (Vː) to signify lengthening of the vowel in the phonetic realization, but crucially it does not signify phonological length. If English were to have phonological long vowels, we might expect this length to be different from that notated here.

(10) Flapping applies only to coronals - a categorical distinction[3]
   a. On a phonetic story we might expect other stops to flap
   b. (Obviously) not conclusive

(11) Authors who've assumed this: Kahn (1976), Selkirk (1982), Turk (1993), Hayes (1995:12)

3.2 Pre-consonantal Lengthening is Phonetic

(12) I will assume that the lengthening of vowels before voiced consonants is a phonetic process, not a phonological one

(13) Proposed as a phonetic universal (Ko 2007)
   a. Notable exceptions: Spanish, Polish, Czech, Saudi Arabic

(14) Vowel length is not contrastive in English
   a. Not conclusive

(15) Authors who've assumed this: Kluender, Diehl, and Wright (1988), House (1961), Chen (1970), Keating (1985)

4 The Data

4.1 Speaker and Equipment

(16) The informant
   a. Female, age 24, non-smoker
   b. From New Orleans, LA (approximately 6 years spent in the Northeast)
   c. No physical or mental illnesses that might impact speech production

(17) The recordings
   a. Edirol R-09 Recorder, Edirol CS-15 Stereo Microphone
   b. Recorded at 44.1 kHz (mono), 192 kbps MP3

(18) Analysis
   a. All analysis was done using Praat on a Mac
   b. Three clear tokens were analyzed of each target were analyzed (25 target words, 75 tokens, see Appendix)

[3]See Turk (1993) for an argument that all stops in English shorten between a stressed and am unstressed syllable

4.2 Elicited Materials

(19) Minimal pairs, differing in their final consonant (/d/ or /t/)

(20) Versions of the above, with a /+er/ suffix

(21) Example: 'seed' / 'seat', 'seeder' / 'seater'

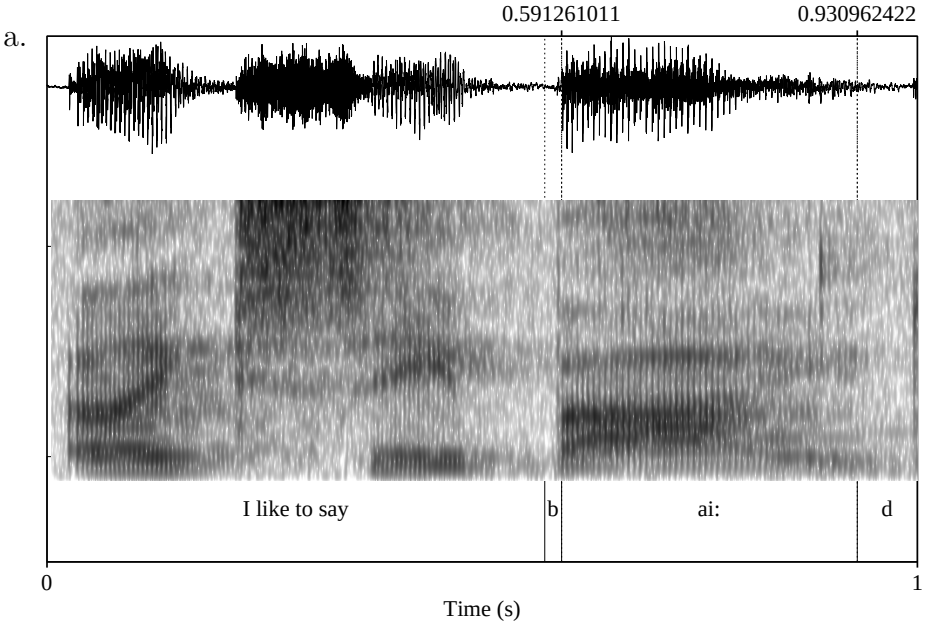
a. In the '-er' versions, the /t/ or /d/ is realized as ⟦ɾ⟧

4.3 Measurements

(22) The length of the vowel preceeding the ⟦t⟧, ⟦d⟧, or ⟦ɾ⟧ was measured and compared with the other member of the pair

(23) 'bide' (/baid/ → [baid] → ⟦baiːd⟧), V ≈ 339ms

a.

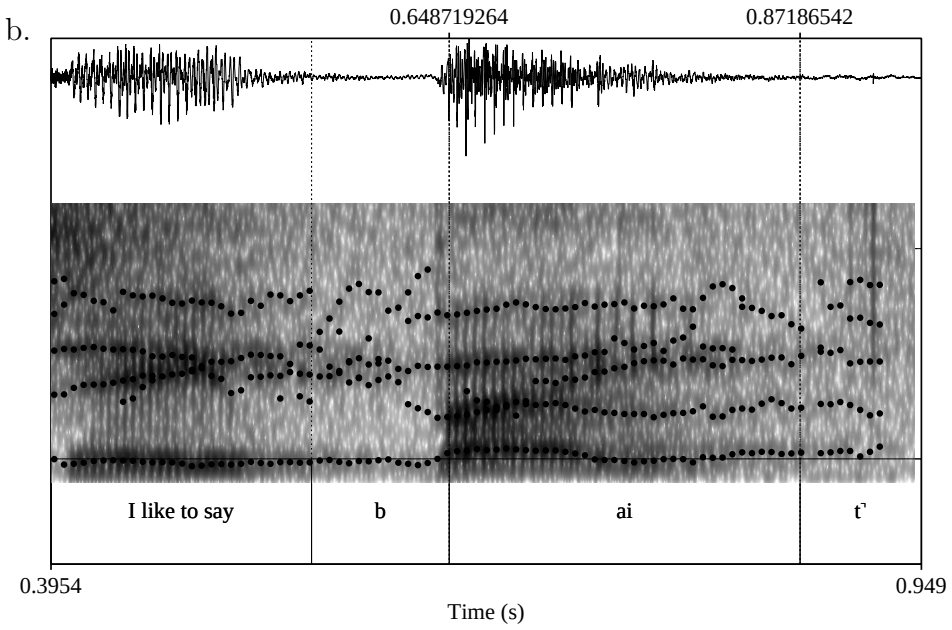


(24) 'bite' (/bait/ → [bait] → ⟦baitˀ⟧), V ≈ 223ms

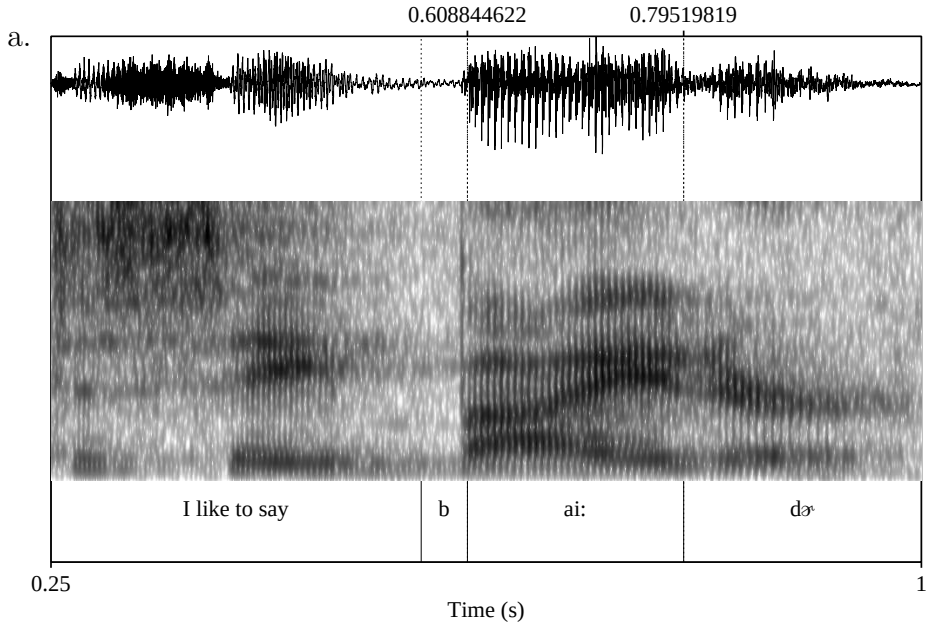
a. Note that the /t/ is unreleased ⟦tˀ⟧- making it hard to tell where the vowel ends

i. To keep consistent, vowel end time was set as the point when the Praat formant tracker made a break[4]

[4]This method is imprecise at best, but at least provides a somewhat standard benchmark

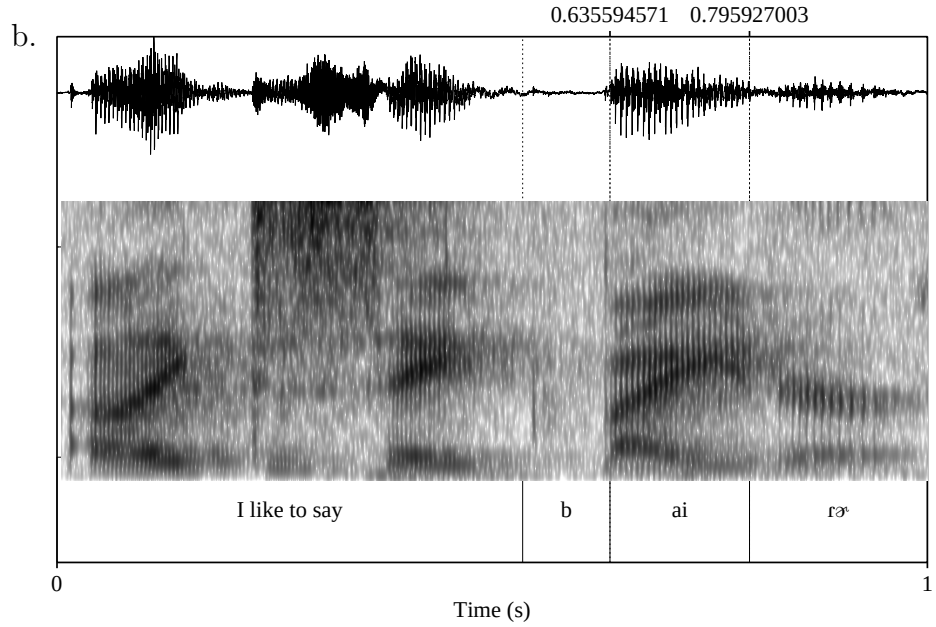


(25) 'bider' (/baid+ɚ/ → [bairɚ] → [[bairɚ]]), V ≈ 186ms



(26) 'biter' (/bait+ɚ/ → [bairɚ] → [[bairɚ]]), V ≈ 160ms

a. This is *shorter* than the vowel preceding the underlyingly voiced consonant in (25) - surprising, considering both are phonetically voiced



4.4 Results

(27) The generalizations

a. In all pairs, the version with the input voiceless consonant had a shorter vowel duration than the version with the input voiced consonant

b. This was true even when the output was neutralized to voiced [ɾ] - the opaque condition (e.g. 'seed' > 'seat', 'seeder' > 'seater')

(28) The average difference between all voiced/voiceless pair-members was 69.6$\bar{1}$ms

(29) The average difference between non-flapped pair-members (e.g. 'seed' > 'seat') was 108.4ms

(30) The average difference between flapped pair-members (e.g. 'seeder' >'seater') was 32.8ms

4.5 Implications

(31) The phonetics seems to be sensitive to whether a flap corresponds to a voiced or voiceless input segment - if the input correspondent is voiced, the preceding vowel gets lengthened

a. So, the phonetics should be able to see the input correspondent of flaps

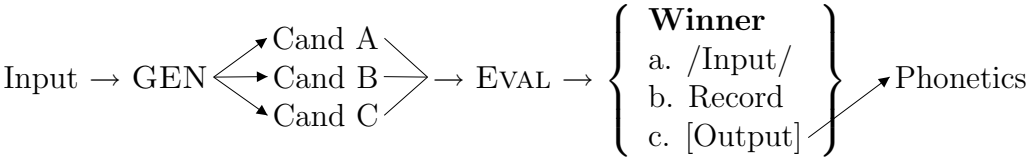
(32) The length distinction in 'seeder'/'seater' pairs is not as large as that in 'seed'/'seat'

a. In other words, the length distinction in opaque pairs is not as large as that in non-opaque pairs

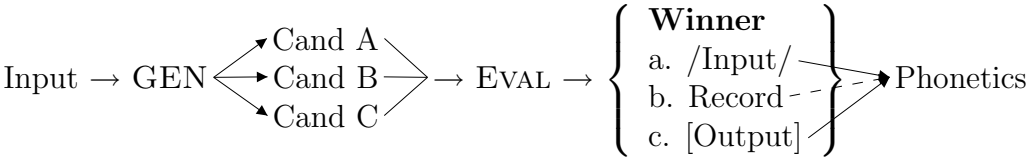
b. So, the phonetics should know when it's being conditioned by the phonological output (a normal scenario) vs. an input correspondent (an opaque situation) - phonological conditioning gets less lengthening

5 The Proposed Model: A Skeleton

(33) One possible way to account for this data is to allow the phonetics to see more of the winning candidate that in the standard model (repeated here as (34))

(34) 

(35) The proposed model in (36) allows access to the input and output (and possibly access to the record)

(36) 

(37) Phonetic processes should be able to be triggered by the input as well as the output

(38) A "derivation"[5]

a. The phonetics sees a (voiced) flap

b. A phonetic rule says "increase duration of vowels preceding a voiced consonant"

c. Before changing the vowel's length, the phonetics looks at the flap's input correspondent

d. If that correspondent is not voiced, the phonetics will not lengthen the preceding vowel (a more economical choice)

e. If that correspondent is voiced, the phonetics has no choice but to make the (expensive) change

(39) What is the "record"?

a. If the record is simply correspondence relations between input and output segments and calculations of differences between them, then the record is necessarily accessible to the phonetics on this view by virtue of allowing the phonetics access to the input, output, and correspondence

[5]I use the term "derivation" here and throughout very loosely

b. If the record is a list of changes between input and output, or various stages the candidate underwent to become the output, we might expect phonetic processes to be triggered by steps in such a "derivation"[6]

(40) The can of worms

a. Why does the phonetics not *always* look at the input? Is there a "triggering mechanism" that allows for input-lookup? Perhaps underspecification?

6 Effects of Morphological Structure on Phonetics

(41) Further support for the proposed model can be found by looking at other aspects of the phonological output - in particular, whether or not morphological structure is represented in the phonological output

a. The proposed model can provide the phonetics access to the morphological structure without the need for morphological structure in the phonological output

(42) The standard assumption seems to be that phonological output contains morphological structure

(43) It is not entirely obvious that this is necessarily true (c.f. Braver (2008))

(44) Two questions

a. Does morphological structure affect the phonetics?

b. If so, how does the phonetics access morphological structure?

6.1 Cases of Morphological Effects

(45) The following cases all suggest that the phonetics needs to have access to morphological structure - a situation possible under the proposed model, even if the phonological output does not include any such structure

(46) Lheidli intervocalic consonants are significantly longer when at a morpheme boundary[7] (Bird 2004)

a. The phonetics needs to see morpheme boundaries in order to apply consonant lengthening

(47) The [xh] cluster in the Dutch morphemes +igheid' [+əxhɛit], '+ig+heid' [+əx + hɛit], and '+heid' [+hɛit] (when following a root ending in /x/), which

[6]Note that the parallel nature of standard OT does not require that GEN create a given candidate in its entirety in a single step; rather it only requires that EVAL evaluate the final form of a candidate sent to it

[7]This case, and the rest cited here are not without their complications. See Braver (2008) for a more complete summary

vary only in their morphological structure, differ in length (Pluymaekers et al. 2006)

a. The phonetics must be able to see morphological structure in order to account for the length of the [xh] cluster

(48) Epenthetic [ɹ] in Boston English, is realized differently from underlying (morphologically affiliated) /ɹ/ in other English dialects

a. If the phonetics can see that epenthetic [ɹ] does not belong to any morpheme (as is thought of epenthetic segments), it can potentially realize it differently

6.2 Getting Morphology from the Input

(49) One way to account for the cases in §6.1 is to assume that the output contains morphological structure

(50) An alternative method ('reference'): the morphological structure is (by hypothesis) already encoded in the phonological input, so just look there

a. On the model proposed in §5, the phonetics has access to the input, and therefore to the morphological structure - thus, there is no need to include such structure in the output

b. Thus, the cases in §6.1 receive a simple explanation

7 Conclusion

(51) If this model is correct, it makes some strong predictions

(52) We should see many more cases of "phonetic opacity"

(53) The restricted access to the phonology that the phonetics used to have has to be rethought

(54) On the proposed model, phonetic effects of morphological structure can be explained by reference to the phonological input

References

Bird, Sonya (2004). *Lheidli Intervocalic Consonants: Phonetic and Morphological Effects. Journal of the International Phonetic Association* 34(1) pp. 69–91.

Braver, Aaron (2008). *Does Phonological Output Contain Morphological Structure? Evidence from Consistency of Exponence and Fine Phonetic Details.* Presentation at HUMDRUM 2008. Rutgers University.

Chen, Matthew (1970). *Vowel Length Variation as a Function of the Voicing of the Consonant Environment. Phonetica* 22 pp. 129–159.

Hayes, Bruce (1995). *Metrical Stress Theory: Principles and Case Studies.* University of Chicago Press.

House, Arthur S (1961). *On Vowel Duration in English. Journal of the Acoustical Society of America* 33 pp. 1174–1178.

Kahn, Daniel (1976). *Syllable-based Generalizations in English Phonology.* Ph.D. thesis, Massachusetts Institute of Technology.

Keating, Pat (1985). *Universal Phonetics and the Organization of Grammars.* In Victoria Fromkin (ed.), *Phonetic Linguistics: Essays in Honor of Peter Ladefoged*, pp. 115–132. Academic Press, Burlington, MA.

Keith Kleunder, Beverly A Wright, Randy L Diehl (1988). *Vowel-Length Differences Before Voiced and Voiceless Consonants: An Auditory Explanation. Journal of Phonetics* 16 pp. 153–169.

Ko, Eon-Suk (2007). *Acquisition of Vowel Duration in Children Speaking American English.* In *Proceedings of INTERSPEECH.*

Perkins, Jeremy (2008). *Canadian Diphthong Raising.* Handout from presentation in Phonology II, Spring 2008, Rutgers University.

Pluymaekers, Mark, Mirjam Ernestus, et al. (2006). *Effects of Morphological Structure on Fine Phonetic Details: The Case of Dutch -igheid.* In *10th Conference on Laboratory Phonology*, pp. 53–54. `http://www.lpl.univ-aix.fr/~labphon10/abstracts/162.pdf`.

Selkirk, Elisabeth (1982). *The Syllable.* In Norval Smith Harry van der Hulst (ed.), *The Structure of Phonological Representations*, 2. Foris, Dordrecht.

Turk, Alice Elizabeth (1993). *Effects of Position-in-Syllable and Stress on Consonant Articulation.* Ph.D. thesis, Cornell University.

Appendix

Token Vowel Lengths (in ms.)							
Word				**Token**			**Avg.**
English	*/Input/*	*[Output]*	*⟦Phonetics⟧*	1	2	3	
'ride'	/ɹaid/	[ɹaid]	⟦ɹaiːd⟧	345	315	295	$318.\bar{3}$
'write'	/ɹait/	[ɹait]	⟦ɹait˺⟧	150	204	201	185
'rider'	/ɹaid+ɚ/	[ɹaiɾɚ]	⟦ɹaiːɾɚ⟧	185	188	173	182
'writer'	/ɹait+ɚ/	[ɹaiɾɚ]	⟦ɹaiɾɚ⟧	138	108	123	123
'bide'	/baid/	[baid]	⟦baiːd⟧	339	353	333	$341.\bar{6}$
'bite'	/bait/	[bait]	⟦bait˺⟧	210	223	214	$215.\bar{6}$
'bider'	/baid+ɚ/	[baiɾɚ]	⟦baiːɾɚ⟧	186	185	181	184
'biter'	/bait+ɚ/	[baiɾɚ]	⟦baiɾɚ⟧	164	160	164	$162.\bar{6}$

Word				**Token**			**Avg.**
English	*/Input/*	*[Output]*	*⟦Phonetics⟧*	1	2	3	
'obeyed'	/oʊbeid/	[oʊbeid]	⟦oʊbeiːd⟧	302	317	326	315
'bait'	/beit/	[beit]	⟦beit⟧	227	238	236	233.$\bar{6}$
'obeyed her'	/oʊbeid+ɚ/	[oʊbeiɾɚ]	⟦oʊbeiːɾɚ⟧	153	185	204	180.$\bar{6}$
'baiter'	/beit+ɚ/	[beiɾɚ]	⟦beiɾɚ⟧	128	141	113	127.$\bar{3}$
'fade'	/feid/	[feid]	⟦feiːd⟧	356	373	325	356.$\bar{3}$
'fate'	/feit/	[feit]	⟦feit˺⟧	217	244	264	241.$\bar{6}$
'fader'	/feid+ɚ/	[feiɾɚ]	⟦feiːɾɚ⟧	157	163	164	161.$\bar{3}$
'fater'	/feit+ɚ/	[feiɾɚ]	⟦feiɾɚ⟧	147	146	153	148.$\bar{6}$
'seed'	/sijd/	[sijd]	⟦sijːd⟧	336	310	270	305.$\bar{3}$
'seat'	/sijt/	[sijt]	⟦sijt˺⟧	207	194	240	213.$\bar{6}$
'seeder'	/sijd+ɚ/	[sijɾɚ]	⟦sijːɾɚ⟧	190	174	143	169
'seater'	/sijt+ɚ/	[sijɾɚ]	⟦sijɾɚ⟧	125	106	101	110.$\bar{6}$
'sate'	/seit/	[seit]	⟦seit˺⟧	234	233	226	231
'Seder'[8]	/seidɚ/	[seiɾɚ]	⟦seiːɾɚ⟧	166	164	167	165.$\bar{6}$
'sater'	/seit+ɚ/	[seiɾɚ]	⟦seiɾɚ⟧	149	151	144	148.$\bar{6}$
'pay-delay'	/pei+dəlei/	[peidəlei]	⟦peiːdəlei⟧	184	234	240	219.$\bar{3}$
'pay-today'	/pei+tədei/	[peitəɾei]	⟦peitəɾei⟧	129	156	160	148.$\bar{3}$

[8]This form is monomorphemic, but was included as a baseline comparison