Vowel Reduction and Merger in Pacific Northwest English

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Research Questions:

(1) Does vowel reduction manifest differently in vowels undergoing "change in progress" than in vowels not undergoing change?
(2) How much style-related shift do we see in stable PNWE vowels vs. changing vowels?

1. General Background

1.1 Similarities between Pacific Northwestern English and other dialects

Previous research into the English spoken in the Pacific Northwestern US (PNWE hereafter) gives us the broad outlines of a vowel system that shares general features with Mainstream US English (Wassink et al. 2009), including positions for /iː, ɪ, oʊ, ʌ, ʊ/. However, the term "Mainstream" or "General" English sometimes pools together dialect regions with divergent phonetic realizations of segments in the same phonemic systems, such as the Inland North, Mid-Atlantic states and California (Figs. 1, 2; Hillenbrand et al. 1995, Labov et al. 2006):

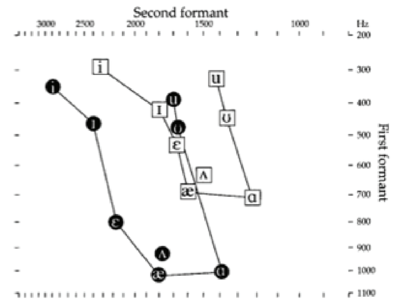


Fig. 1 California English (source: Hagiwara, 1997)

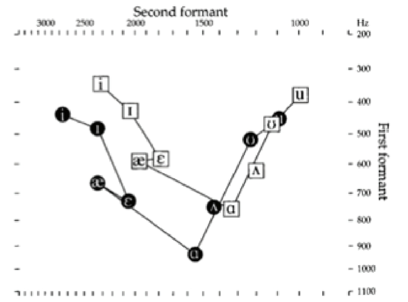


Fig. 2. Inland North English (source: Hillenbrand et al., 1995, adapted by Hagiwara, 1997)

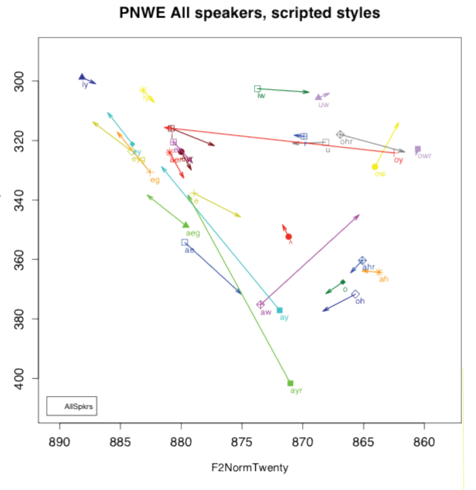


Fig. 3 Pacific Northwest English (source: Wassink et al. 2009. note: formant values presented are extrinsically-normalized, scaled Hz)

1.2 Differences from Mainstream US English

PNWE also diverges...
1. nearly completed low-back merger of (a~ɔ) COT~CAUGHT (see Table 1 for Historic Word Class Codes)
2. monophthongal /eː/ BAIT and /oʊ/ BOAT (Fig. 4)
3. 2 two-way mergers restricted to pre-velar position:
   - /æg/ BAG~/ɛg/ BEG found both in males and females
   - /ɛg/ BEG, /eyg/ BAKE found mainly in females
   - note: (ae)-raising differs from the tensing and raising pattern (e.g. to [eə]) of the Inland North (Hillenbrand et al., 1995; Labov et al. 2006)
4. little fronting of (uw) BOOT, as is found in California (Hagiwara, 1997)

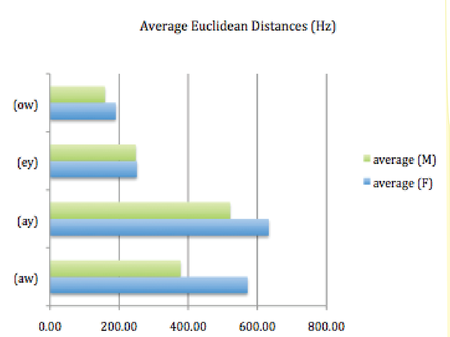


Fig. 4. Average vector lengths for four historically diphthongal vowels.

Table 1: Historic Word Class Codes
14 Targeted vowels:

IPA	/iː/	/ɪ/	/eː/	/ɛ/	/æ/	/a/	/ɔ/	/ʌ/	/ʊ/	/u/	/aj/	/ɔj/	/oʊ/	/aʊ/
Historic Word Class(es)	(ij)	(i)	(ey)	(e)	(ae)	(o)	(oh)	(uh)	(u)	(uw), (iw)	(aj)	(oy)	(ow)	(aw)

1.3 Problem:

A long-held assumption stands in acoustic phonetics that reduction is greater in casual speech than in controlled styles (Swerts et al 2003; Byrd 1994; Lindblom 1990).

Consequences of this assumption:
~ Few phonetic studies have actually examined the phonetic features of casual, connected speech. Research reflects concomitant emphasis on citation styles.
~ Little is known regarding whether there are different degrees of systematic reduction for different types of sounds produced in casual speech.

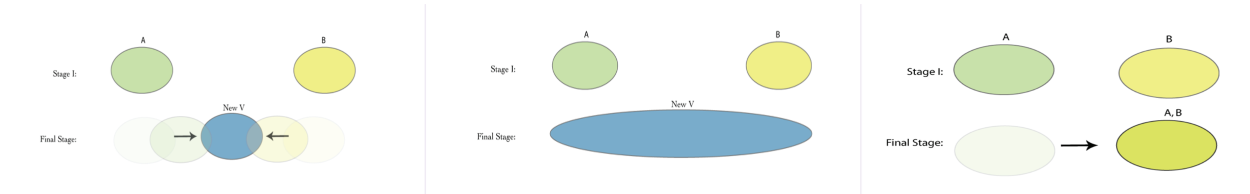
1.4 Duration-dependent vowel reduction (DDVR):

DDVR refers to the displacement of formant patterns in vowels produced with short durations (whether phonologically long or short). Two types of DDVR have been the focus of phonetic experimentation, spectral undershoot (Moon & Lindblom, 1994) and centralization. This research focuses on centralization.

Centralization:
Vowel centralization is a context-independent effect. Studies show a tendency for front vowels such as /ɪ, ɛ, eɪ/ (HWC codes i, e, ey) to emerge with a lower F2 (occur more centrally in the vowel space, or to be more schwa-like) at short durations due to economy of effort (Lindblom, 1990).

1.5 Stable vs. instability in vowel systems undergoing change in progress

Mergers (the coalescence of vowel qualities resulting in loss of phonological contrast) yield a destabilization of a particular kind. As elements approximate one another, spectral targets shift. Merger may take different forms (in examples to follow in Figs. 5a-c, Vowel B is the affected or moving element in the merger unless specified otherwise):



(Fig. 5a) merger by approximation: Both A and B coalesce, resulting in a new vowel quality intermediate to the original phonetic values.

(Fig. 5b) merger by expansion: phoneme B assumes the mean value of one of the original distributions, but with an enlarged class membership. Mergers by approximation and expansion may be indistinguishable in their intermediate phases.

(Fig. 5c) merger by transfer: unidirectional shift in which elements of distribution A are transferred into B with no intermediate phonetic form.

1.6 Hypotheses:

Vowels undergoing merger by approximation may not have stable spectral targets. This may mean a greater tendency to centralize than might otherwise be expected (for stable vowels) in casual speech (e.g., under language-general phonetic pressures).

Unmerged Speakers: vowels are stable and distributions are more widely dispersed in acoustic space. Stable vowels will show standard DDVR (greater reduction in casual than in formal speech). We assume there are auditory limits on possible spectral expansion (the tendency of vowels to be maximally dispersed in phonetic space to facilitate the maintenance of phonetic contrast (Ohala, 1993)). Note: we also expect stability for merged speakers in the parts of their vowel system uninvolved in merger.

Merged speakers: distributions undergoing change will show greater spectral variability (perhaps in all tasks). This greater variability manifests instrumentally in larger deviations from the mean. No clear prediction can be made as to whether this will mean centralization, or just greater spread/expansion in the distribution (e.g., in F1).
- overlap fractions can help us see vowel distribution expansion
- means vectors can indicate centralization

2. Methods

Data Collection
15 speakers (from a larger sample of 35)
4 males, 11 females
5 Tasks:
- Wordlist Task: "Say _____ again."
- Reading Passage: "The Cat and the Mice"
- Semantic differentials
- Interview Style
- Casual Conversation

Measures:
1. spectral: F1, F2, F3 (onset, 20%, 50%, 80%, offset) (Hz)
2. temporal: duration (sec)

Dependent Variables:
1. stable monophthongs (i), (ae)
2. stable diphthongs (iy), (ey)
3. changing monophthongs (eg), (aeg)
4. (System contains no changing diphthongs. Environment not included)

Independent Variables:
1. Task (2 levels)
   a. SCRIPTED (WdList + RdgPsg)
   b. UNSCRIPTED (Conv + SemDiffs + Int)
2. Speaker

Analysis Techniques:
1. Formant data normalized using a speaker-intrinsic method, adapted from Nearey (1977), using NORM software (Kendall and Thomas, 2009).
2. Duration data were submitted to Z-score normalization.
3. Normalized data (F1, F2, duration) were evaluated for overlap. Quantification and visualization achieved using SOAM, implemented using VOIS3D software (Wassink 1999, 2006).
4. Multivariate ANOVA (overlap data).

The Spectral Overlap Assessment Metric

Interpreting overlap fractions:
Overlap fractions reflect extent of protrusion by area (in 2-D) or volume (in 3-D) of two vowel distributions. 3-D calculations reveal the combined contribution of spectral (F1 and F2) and temporal features (duration) to separation of vowel distributions. Note that the major shortcoming of the approach is that it is a single-point measure (each vowel token is represented by a single datapoint only).

Form:	Meaning:	
($\Omega_{speakerID, vowel\ pair}$) e.g., $\Omega_{21,eg\sim aeg}$	= 0.20	indicates volume overlap of 20%
	= 0.47	indicates volume overlap of 47%
	= 0.98	indicates volume overlap of 98%

The heuristics used for classifying distributions as non-, partially-, or completely overlapping are shown below. Because vowel duration enhances the vowel quality contrast between long and short vowels in English, we expect that overlap fractions in 3-D (which includes duration as Z-axis) will be smaller than those in 2-D.

Overlap Heuristics:
0-20% = separation
21-74% = partial overlap
75-100% = complete spectral overlap

4.0 Overall Summary

PNWE speakers differ in extent of their participation in the low-front prevelar merger.

Level of merger participation appears to influence vowel reduction, with the most-merged speaker reducing LEAST in casual styles.

As expected, overlap between tense~lax vowel distributions generally increases in unscripted speech. However, contrary to expectations, stable vowel pairs (such as (iy~i)) tend to show this increase in overlap more than merging vowel pairs. Speakers appear to be more precisely maintaining the spectral locations and temporal features of their merging vowels as they shift from casual speech to careful speech.

Vowels do not always display reduction in casual speech.

3.0 Results

3.1 EXPERIMENT I: Participation in the Low-Front Merger

Focusing on by-speaker data, do we see differences in participation in the low-front merger? YES.

Table 2. Merger participation, by speaker. 3D overlap fractions are presented for scripted tasks only. Highlighting indicates word classes undergoing change (merger) in which speakers display complete overlap. Cutoff values: 0-20% (Ω≤ .20) is considered "no spectral overlap", 21-74% (Ω=.21-.74) is considered "partial spectral overlap"; >75% (Ω≥.75) is considered "complete spectral overlap". (ey~e) includes non-prevelar contexts only.

								Merging Word Classes									
Merger Category	Speaker ID	(iy~i)			(ey~e)			(ey~eg)			(ey~aeg)			(eg~aeg)			
		None	Partial	Compl.	None	Partial	Compl.	None	Partial	Compl.	None	Partial	Compl.	None	Partial	Compl.	
Complete																	
3 Wd classes	SB1CF2A		0.68				0.65			0.75			0.89			0.82	
	SS6AF1C		0.29					0.06		0.83			0.83			1.00	
2	(n/a)																
1	SV11CM2G	0.00			0.00				0.27		0.17					0.84	
	SV12CM2H	0.18			0.04				0.48		0.15					0.94	
	SS5AM2C		0.27		0.04				0.33			0.28				0.78	
	SH17CF1K	0.01			0.14					0.71		0.27			0.38		
	SU9CF3E	0.07			0.03					0.91		0.43			0.56		
Partial																	
3	SW4CF2B	0.19			0.09				0.61			0.25			0.73		
	SN8CF1D	0.10			0.06				0.46			0.58			0.74		
	SL13CF1I	0.17			0.18				0.55			0.28			0.67		
	SP15CF1J	0.18			0.07				0.61			0.22			0.67		
2	SE16CF1J		0.36		0.00				0.29		0.02				0.29		
	SN7CF2D		0.27		0.05				0.37		0.17				0.63		
	SK14CM2I	0.00			0.00				0.23		0.03				0.34		
1	ST26AF1N	0.01			0.00			0.16			0.02				0.68		

Observations:
1. (iy~i), (ey~e): These tense~lax pairs tend toward extreme separation (Ω=0.0 - 0.19) for all speakers.
2. (eg~aeg): We observe 5 speakers completely merging on this pair (with the remaining 10 showing partial overlap). Two of these speakers raise both (aeg, eg) to (eyg).
3. (ey~eg): Merger of these vowels is nearly as common as (eg~aeg) in this sample. Only 2 speakers show no overlap at all for this pair.
4. (ey~aeg): Merger of these classes is less advanced. Two speakers raise (aeg) all the way to (eyg) (an additional 7 show partial merger, and 6 show no approximation at all).

3.2 EXPERIMENT II: Reduction In Stable Vs. Changing Vowels

Focusing on by-task data, do we see differences in overlap patterns for stable vowels and changing vowels (comparing casual to careful speech)? YES.

Table 3. Reduction comparison in "reflexive pairings", for one merged and two unmerged speakers. 3D overlap fractions are presented for scripted and unscripted tasks. (*) indicates style-shift. Cutoff values as above in Table 2. Speakers included 3 Subjects from Exp. 1,2 exemplifying the most merged (SS6, SN7) and least merged (SB1) systems in the sample.

		Stable Word Classes						Merging Word Classes		
Merger		(iy~iy)			(i~i)			(eg~eg)		
Category	Speaker ID	None	Partial	Compl.	None	Partial	Compl.	None	Partial	Compl.
Unmerged	SN7CF2D		0.37 *				0.89	0.00 *		
	SS6AF1C		0.60 *				0.76	0.00 *		
Merged	SB1CF2A			1.00			0.94			1.00

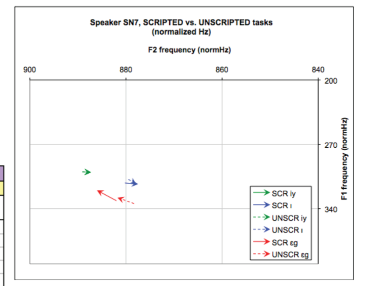
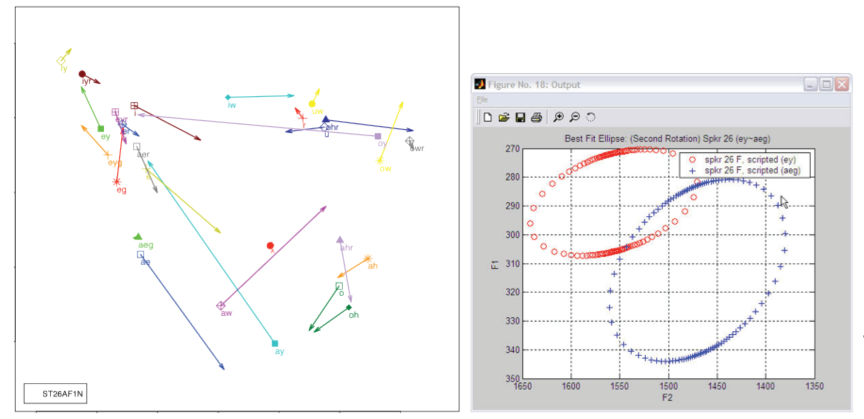


Fig. 9: Younger F, SN7. Means vectors, 20%, 80%.

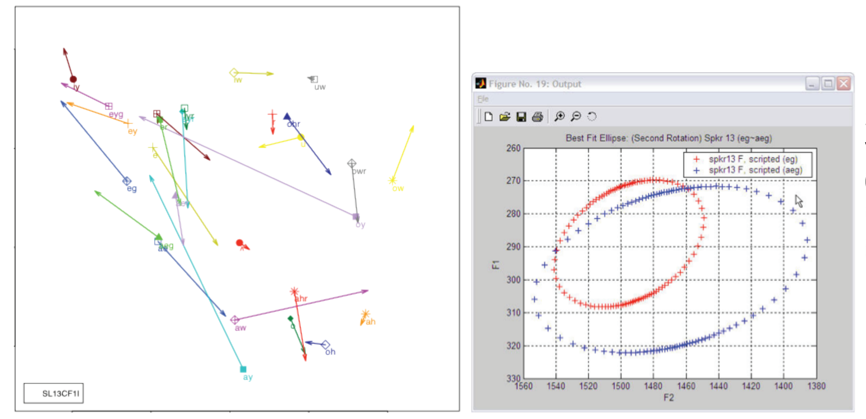
Observations:
1. **Self-comparisons (stable vowels):** Extent of overlap of a stable vowel (iy~iy, i~i) in its scripted guise with itself in its unscripted guise indicates style-related shift. Recall that **low** values signify that vowel distributions occupy **different** spectral locations. **High** values indicate **shared** locations. Surprisingly, it is the most-merged speaker who shows the least style-related shift in reflexive stable vowel pair comparisons.

Overall, we find three patterns of separation Figs. 6-8):



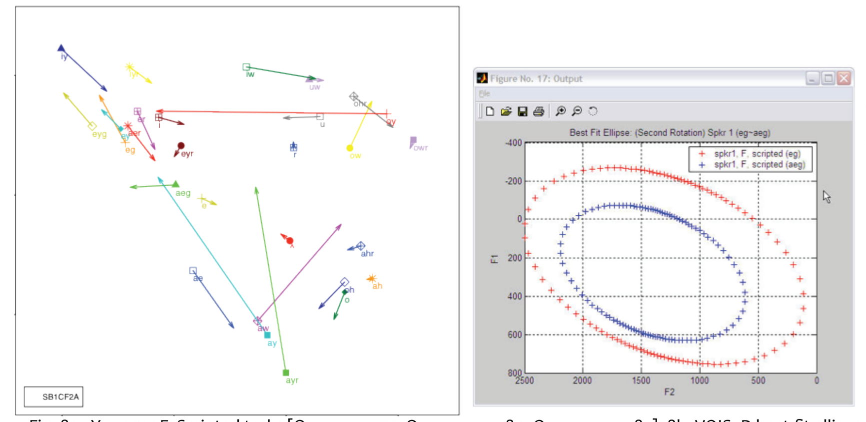
Pattern 1. All vowels show spectral separation (or partial overlap). These speakers show least evidence of participating in the merger (and tend to be the eldest in the sample).

Fig. 6a. Older F, Scripted tasks [$\Omega_{26,ey\sim eg}$= .16, $\Omega_{26,ey\sim aeg}$ =.02, $\Omega_{26,eg\sim aeg}$ =.68], b. VOIS3D best-fit ellipses for (ey~aeg).



Pattern 2. Raising of some or all changing vowels (approximation), but no completely merged pairs.

Fig. 7a. Younger F, Scripted tasks [$\Omega_{13,ey\sim eg}$= .55, $\Omega_{13,ey\sim aeg}$ =.28, $\Omega_{13,eg\sim aeg}$ =.67]. 7b. VOIS3D best-fit ellipses for (eg~aeg).



Pattern 3. Raising and merging of all changing vowels.

Fig. 8a. Younger F, Scripted tasks [$\Omega_{1,ey\sim eg}$= .75, $\Omega_{1,ey\sim aeg}$ =.89, $\Omega_{1,eg\sim aeg}$ =.82]. 8b. VOIS3D best-fit ellipses for (eg~aeg).

2. **Self-comparisons (changing vowel eg~eg):** Again, it is the most-merged speaker who shows the least style-related shift.
3. **Centralization:** Productions for high front vowels that are more central in acoustic space will show shift toward lower F2 values, and higher F1 values (i.e., vector shift to right). By-speaker analysis of the reflexive pair data shows that only vowel pair for one speaker (SN7) shows any evidence of shift toward center of vowel space.
4. **Non-reflexive comparisons across styles** (iy~i vs. eg~ae): As expected, overlaps generally increase in unscripted speech. However, contrary to expectations in §1.6, **stable pairs tend to show this pattern more than merging ones** (F=3.082, p=0.006).
   - Stable vowels [$\Omega_{allspkrs,\ SCR-UNSCR}$]: avg. = -0.63, stdev. = 0.36
   - Unstable vowels [$\Omega_{allspkrs,\ SCR-UNSCR}$]: avg. = -0.13, stdev. = 0.33

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acknowledgements: This research was supported by National Science Foundation grant BCS#0643374. The author wishes to express thanks to the members of the U of Washington Sociolinguistics and Phonetics laboratories.