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A Survey of English Vowel Spaces of Asian American Californians

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Abstract

A phonetic study of the vowel spaces of 535 young speakers of Californian English showed that participation in the California Vowel Shift, a sound change unique to the West Coast region of the United States, varied depending on the speaker's self-identified ethnicity. For example, the fronting of the pre-nasal HAND vowel varied by ethnicity, with White speakers participating the most and Chinese and South Asian speakers participating less. In another example, Korean and South Asian speakers of Californian English had a more fronted FOOT vowel than the White speakers. Overall, the study confirms that CVS is present in almost all young speakers of Californian English, although the degree of participation for any individual speaker is variable on account of several interdependent social factors.

1 Introduction

This is a study on the English spoken by Americans of Asian descent living in California. Specifically, it will look at differences in vowel qualities between English speakers of various ethnic or national origins and compare them to the latest findings on Californian English.

1.1 On California

Of the fifty states, California is by far the most populous (12% of the US total) and the most ethnically and culturally diverse, with higher percentages of Asian, American Indian, Pacific Islander, Hispanic or Latino, and multiracial residents than the US at large and an

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extremely large proportion of households speaking a language other than English at home, at 43.7%, compared to the country's 20.7% (United States Census Bureau).

California's geographic proximity to East Asia and history of immigration help explain its high percentage of residents of Asian descent, second only to Hawaii – although in raw numbers, Asian Californians are still the largest group. Of nearly 5.6 million self-identified Asian Californians, the seven largest groups are Filipino, Chinese, Vietnamese, Indian, Korean, Japanese, and Taiwanese. Although Chinese and Japanese immigrants first arrived on the West Coast in the mid-nineteenth century, the largest influx of Asian immigrants began in the mid-1960's and has continued to rise until the present day.

When immigrant communities are established in a new host country, they generally continue to speak their native languages. In California, languages spoken at home other than English include Spanish, Mandarin, Cantonese, Tagalog, Vietnamese, Korean, and Persian (Farsi). Nearly 44% of Californians are native speakers of a language other than English, and 74% of those also speak English natively, meaning that they were raised bilingual (Modern Language Association).

However, due to the nature of this kind of language contact, what is known as the second generation will shift from using the mother tongue to using the dominant or ambient language, and by the third generation there is dramatic, if not complete, loss of the mother tongue (Portes and Hao, 1998). The question of the current study is what the English of the second generation sounds like and how it may align with or differ from what is considered to be "California English".

1.2 On California English

Studies on the dialect of English spoken in California have assumed historical leveling (given its long history of immigration from other parts of the United States) and demonstrated the rise of certain phonological patterns distinct to this state, beginning with the 1986 seminar that first proposed the California Vowel Shift (Hinton et al., 1987; Luthin, 1987) by comparing vowel qualities in contemporaneous elicitations to those described in Reed's Linguistic Atlas of the Pacific Coast (1952). Subsequent research has confirmed CVS among White Californians in urban and rural locations (Hagiwara, 1997; Podesva et al., 2015a), debated its presence among Californians of Mexican descent (i.e. speakers of 'Chicano English', see Fought, 1999; Eckert, 2008a), and connected its use to gender identity (Kennedy and Grama, 2012) and indexing of a gay male persona (Podesva, 2011).

The majority of this research has been done on the speech of White Californians. Less attention has been given to English speakers who identify as non-White Hispanic, Black, or Asian. In the earliest studies, Asian American speakers in particular were simply tossed into the 'Anglo' category, as if there were no relevant distinctions between the two. However, Mendoza-Denton and Iwai (1993) found some differences in vowel quality based on ethnicity (Japanese American compared to White American) and age, while Hall-Lew (2011) found evidence that Asian-identifying San Franciscans might actually be leading one of the changes that marks the California Vowel shift (namely, /u/-fronting), though otherwise show no large difference.

Given the relatively recent documentation of such phonetic shifts in California English, it could be hypothesized that the sound changes are currently underway. Hall-Lew (2011) argues in an apparent-time study with residents of San Francisco that /u/-fronting is complete. However, social attributes of speakers such as ethnicity, class, and network are also factors that may affect the amount of shift observed in a person's speech (see Fought, 1999; Eckert, 2008a; Podesva, 2011; Podesva et al., 2015a).

1.3 On the California Vowel Shift

The California Vowel Shift, as evidenced by historical and contemporary studies of the English spoken by ethnically Caucasian, Asian, and Latino residents of California, is is most marked by a fronted /u/, a lowered /ɪ/, a backed /ɛ/, and the merger of low back vowels /ɑ/ and /ɔ/ (known commonly as the *cot-caught* merger). In general, this looks like a counterclockwise shift in which back vowels become fronted, high front vowels lower, and low front vowels become more open. In addition, the low front vowel /æ/ is subject to a phonologically conditioned split: raising and tensing before final nasal consonants (as in *lamb* or *handstand*) while lowering and opening elsewhere.

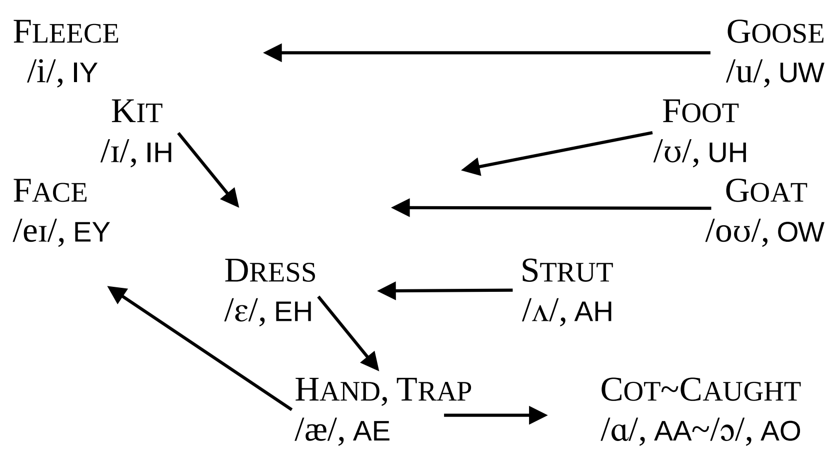


Figure 1: California Vowel Shift, adapted from Hall-Lew (2009).

Figure (1) illustrates the chain shift that is underway (or perhaps complete) in California. In addition to IPA symbols, I have included representative words that contain each vowel, as well as the ARPABET codes for each vowel, since ARPABET was used in data encoding and visualization. Henceforth each vowel will be referred to in the paper using its representative word or ARPABET code and represented in figures using its ARPABET code.

1.4 On Asian Californians

How do non-White Californians actually stack up against the theorized California Vowel Shift? Labov once hypothesized that speakers of minority ethnic groups would not participate in local sound changes (2001). But this idea has been under scrutiny more recently, as studies find a more complex relationship between minority groups and the sound patterns of the majority (e.g., Fought, 2006), especially in areas with understudied ethnic groups or regions that are "majority minority", such as California. There are likely also other influencing factors involved in a given community's participation in sound changes, particularly the use of variables to index various identities and participation in a changing linguistic marketplace (see Eckert, 2008a and Hall-Lew, 2009).

Luthin (1987) remarked that "it doesn't matter where [young Californians'] parents or their grandparents came from before they settled in California; they could be from Germany, Georgia, New Jersey, Ohio, Pennsylvania, Russia, or Singapore... The present generation is more likely to talk like one another than like anybody else" (312). As far as generalizations go, this one has been fairly well corroborated. But it is indeed a generalization, and the present study aims to add nuance to our understanding of California English.

The California Vowel Shift and other attributes of California English, such as slang or prosodic uptalk, are for most the clearest 'exemplar' of Californian "surfer bro" or "valley girl" personae often portrayed in music, television, and movies. But these characters are most often stereotypically imagined as White. And in the past literature, only single Asian ethnicities have been selected for study (e.g., Chinese Americans in Hall-Lew (2009) or Japanese Americans in Mendoza-Denton and Iwai (1993)), with no study endeavoring to observe large numbers of different Asian ethnicities in comparison to one another and to the White "norm".

To what extent do Asian-identified Californians follow the patterns of California English as currently depicted in the academic literature and in popular media? Do they participate fully and equally across subgroups in CVS, as Hinton et al. (1987) assumed, avoid participating in it, as Labov (2001) hypothesized, lead in some aspects only (Hall-Lew, 2009), or something else? For example, do Asian Americans as a whole front their GOOSE vowel to the same extent as their White peers? And do Korean Americans and Chinese Americans (two of the largest Asian subgroups) pattern exactly alike, or do they differ in their participation in CVS?

The 2011 Voices of Berkeley project aimed to gather enough data to provide a comprehensive look at the speech of today's young Californians and factor in extremely detailed sociodemographics to explain variation. Included in the corpus is the speech of hundreds of Asian- and White-identifying Californians, as well as information about what languages they speak, ages of acquisition, what languages their parents (and even grandparents) speak, and where they attended high school. Using this corpus, the current study will attempt to fill in gaps and test the claims of previous studies in the observation and analysis of Asian Californian English.

2 Methods

2.1 The Voices of Berkeley Corpus

The Voices of Berkeley project conducted in 2011 collected speech samples from 786 speakers aged 16 to 61 (mean: 19, median: 18) from around the United States and a number of other countries. From this set, the total number of speakers who are from California was 535 (F=354). The explicit goal of the project, as told to the participants, who were all incoming university students, was for them to contribute their voices as data for phonetic research. Participants gave consent to have their voices recorded and studied, and they also were aware that the recordings would be made available to the public (in particular to their fellow students).

In addition, participants were asked to provide in a demographic survey their age, gender, ethnicity, locality (country, state, county, city, and postal code), which languages they spoke (up to four) and at what age they acquired them, the occupations of up to two caregivers and up to four "grandparent" caregivers, as well as the native languages of all of them. The data collection was performed by participants themselves using their own equipment (e.g., a home computer or laptop with a built-in microphone and Internet access), which enabled the logging of precise geographic location in terms of latitude and longitude at the time of participation.

2.1.1 Ethnicity

Of the Californian participants, 240 (F=158) identified as White and 152 (F=109) as Asian (including East Asian, Southeast Asian, South Asian/Indian, and Middle Eastern[1]). This amounted to 28.4% Asian and 44.9% White in the Californian participants subset. Table 1 below shows the number of male and female Californian participants of each ethnic category.

[1]See Appendix A.1 for complete breakdown of ethnic identifiers found in the Voices of Berkeley corpus.

Ethnicity	female	male	total
Chinese	53	17	70
Filipino	5	3	8
Japanese	5	1	6
Korean	14	10	24
Middle Eastern	14	4	18
Southeast Asian	0	1	1
South Asian	10	3	13
Vietnamese	8	14	12
White	158	82	240
Other	87	56	140
Total	354	181	535

Table 1: Self-reported gender and ethnicity in the California subset of the Voices of Berkeley corpus.

2011 census data for the University of California, Berkeley reports a 39% Asian and 30% White undergraduate population[2], where Asian includes Chinese, Filipino, Japanese, Korean, Pacific Islander, South Asian, Vietnamese, and Other Asian (UC Regents). 2011 census data for the state of California reports 13% Asian (only) and 57.6% White (only), where Asian includes Asian Indian, Chinese, Filipino, Japanese, Korean, Vietnamese, and Other Asian (United States Census Bureau).

Ethnicity	VoB corpus	UCB undergrads 2011	CA census 2010
Asian	28.4%	39%	13%
White	44.9%	30%	57.6%

Table 2: Comparison of Asian versus White ethnicities in the Voices of Berkeley corpus and censuses.

To summarize the comparison in Table 2, the Voices of Berkeley corpus has a smaller proportion of Asian-identified speakers than in the university overall, and a much greater proportion of Asian representation compared to the state overall.

[2]UCB undergraduates as a whole are hugely skewed toward Asians, however: the 21% Asian and 38% White reported in the "Availability Pool" of California high school graduates indicates that Asian students are slightly overrepresented at UCB and White students are slightly underrepresented. Note that the UCB census includes out-of-state and international students, but the "Availability Pool" is calculated only for Californian high school graduates.

2.1.2 Languages

Participants in the Voices of Berkeley corpus were allowed to list up to four languages and the estimated ages of acquisition of each language. Within the Californian subset, the number of speakers who identified English as their L1 and no other language was 165 (F=106). The next most common languages listed as L1 or L2 were Spanish, Mandarin, Korean, Cantonese, Farsi, Vietnamese, and Hindi[3]. No participants listed a non-English language as their only language (i.e., all participants spoke English).

Due to the ambiguity inherent in asking for "first language" and "second language" in this kind of survey and the forced-choice nature of the survey, the "L1"/"L2" distinction in participants' responses was collapsed. For example, a speaker who identified Cantonese as their L1 and English as their L2 and a speaker who identified English as their L1 and Cantonese as their L2 were put into the same category, as long as both languages were acquired before the critical period – in this case, age 10. In this way, speakers could be categorized as English monolinguals or English-[Other language] bilinguals.

However, participants who listed Spanish as an L2 were not included in the "bilingual" categorization, due to the frequency of Californian students learning Spanish in school and not attaining true bilingualism[4]. Table 3 below lists the numbers of bilinguals analyzed in the study. In cases where n<4, the statistical tests were run but not used.

Language	female	male	total
Cantonese-English bilingual	10	2	12
Mandarin-English bilingual	37	13	50
Korean-English bilingual	13	10	23
Farsi-English bilingual	9	3	12
Vietnamese-English bilingual	7	4	11
Hindi-English bilingual	7	0	7
English monolingual	106	59	165

Table 3: Self-reported gender and language background in the California subset of the Voices of Berkeley corpus.

2.1.3 Caregiver Languages

The third sociodemographic factor collected in the Voices of Berkeley corpus was the language spoken at home by the participant's caregiver(s), usually a mother and a father.

[3]Although Filipino, Japanese, and Taiwanese were relatively common ethnic identifiers in the corpus, the number of Tagalog and Japanese speakers was too low to be included in the analysis, and the speakers of Taiwanese were excluded because most ethnic Taiwanese listed Mandarin as their L1 or L2.

[4]For the record, 47 Californian participants (F=31) listed Spanish as their L1.

Participants were asked to freely identify the L1 of up to two caregivers (as well as the L1 of the caregivers' caregivers, or the grandparents). Using this data, households where English was not spoken or was not the primary language could be roughly determined.

The categorization was as follows: if the same language was listed as the L1 for both caregivers, the data could be used. For example, if both caregivers spoke Farsi, then the participant was categorized as coming from a "Farsi-speaking household". However, a participant whose first caregiver spoke Cantonese but second caregiver spoke Mandarin would not be counted as coming from either a Cantonese-speaking or Mandarin-speaking household.

Note that this does reduce the number of data points; compare, for example, the total number of Mandarin-English bilingual participants in Table 3 to the total number of participants from Mandarin-speaking households in Table 4 below. Table 4 lists all the caregiver languages used for speaker analysis[5]. Again, in cases where n<4, the statistical tests were run but not used.

Caregiver Language	female	male	total
Cantonese-speaking	5	2	7
Mandarin-speaking	28	11	39
Korean-speaking	10	10	20
Farsi-speaking	6	3	9
Vietnamese-speaking	7	4	11
Tagalog-speaking	4	2	6
English-speaking	152	77	229

Table 4: Self-reported gender and common language background of participants' caregivers in the California subset of the Voices of Berkeley corpus.

The 2011 American Community Survey estimates that 56.8% of Californian households speak English only, but only 9.5% speak "Asian and Pacific Islander" languages. In comparison, 42.8% of speakers in the Voices of Berkeley corpus come from English-only households, and 17% from households where both caregivers speak Cantonese, Mandarin, Korean, Farsi, Vietnamese, or Tagalog.

[5]Interestingly, there were enough Hindi-speaking female participants to warrant analysis, but not enough Hindi-speaking households, which may be a result of caregivers who have different L1 (e.g. Hindi and Punjabi) but raise their children to speak Hindi. On the other hand, there were not enough Tagalog-English bilinguals for analysis, but enough Tagalog-speaking households to make the cut, which may say something about the retention of heritage language in the children's generation.

2.2 Speech Data

Participants in the Voices of Berkeley project used their own computers and microphones and downloaded an applet that would allow the recordings to be collected remotely. The recording quality varied widely, but samples of recordings were screened for quality, and those deemed unusable were excluded from analysis. Also, the recordings of subjects who reported previous speech or hearing disorders were excluded from analysis. The recording stimuli were a set of six sentences modeled after those in the TIMIT database (Garofolo et al., 1993), created for this study in order to elicit specific vowels and vowel contrasts efficiently. See Appendix A.2 for a list of stimuli and the vowels in them.

2.3 Data Analysis

For each speaker in the corpus, all six recordings were run through a script that utilized the Penn Forced aligner (Rosenfelder et al., 2011) to identify the vowels and assign ARPABET codes, then measured formant values for each vowel at three midpoints. Each speaker's vowel trajectory could then be plotted on a standard F1-F2 chart to show not just the vowel space, but the change in vowel space over time. This is useful for illustrating the movement of diphthongs such as OW or diphthongized vowels such as pre-nasal AEN.

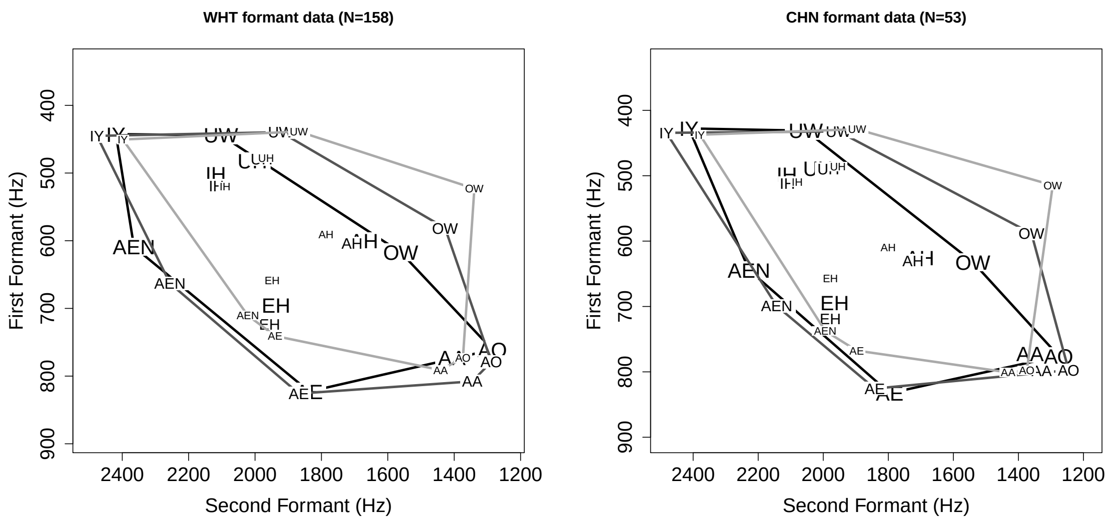
Formant values for all speakers in various categories (e.g. Korean-identifying females or males from English-only households) were averaged and plotted in vowel trajectory charts. In each vowel trajectory chart, the darkest 'hull' represents the position of the vowel at the 25% of the vowel duration; the second 'hull' represents the 50% midpoint; and the lightest 'hull' represents the vowel at 75% of its duration. In addition, the ARPABET symbols for each vowel decrease in size over the duration of the vowel.

Following the data visualization split by gender, all the formant data were log-mean normalized for gender and run through statistical tests using R, including ANOVA and t-tests, to check for significance in the difference of means among groups. (Thus, the vowel space 'hull' figures in the following section are from unnormalized data, but the statistical test results, box plots, and density plots are from normalized data. In addition, all statistical tests were run on only vowel midpoints, not trajectories.)

3 Results

3.1 Variance by Ethnicity

A selection of vowel trajectories of Californian females of different ethnicities can be found in Figures 2 and 3 below. Chinese, Korean, and Vietnamese-identified females are pictured, along with White-identified females for comparison[6].



(a) White-identifying females

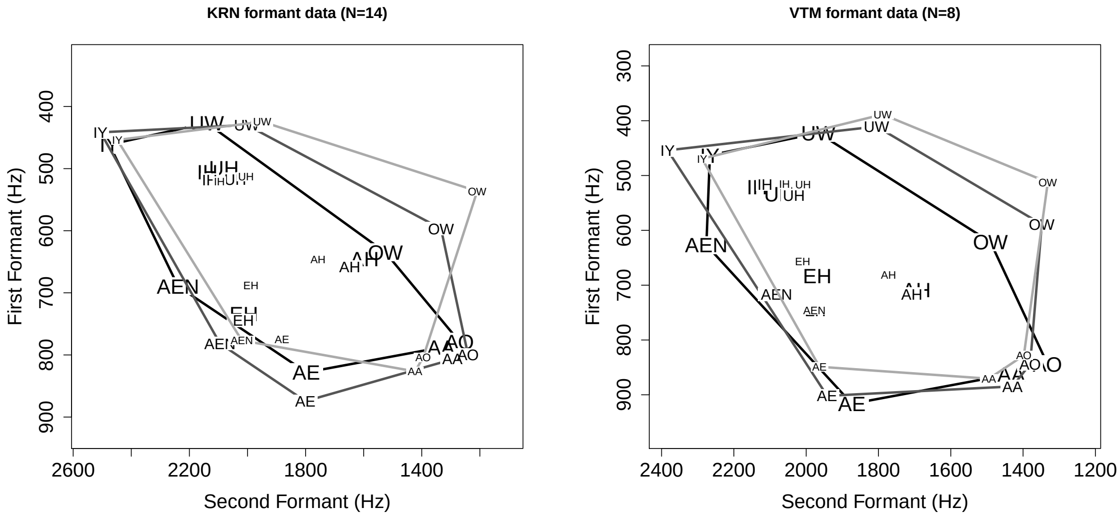
(b) Chinese-identifying females

Figure 2: Female Californian vowel trajectories by ethnic self-identification (1).

Immediately observable from the charts is the fronted nature of the GOOSE vowel for all speakers, regardless of ethnicity. Not only is UW fronted, but it is also diphthongized, with the vowel starting between 1900-2100 Hz (at 25% of the vowel duration) and the offglide trailing backward through the second and third midpoints. The amount of UW-fronting appeared to vary among ethnic groups, but this was not corroborated by statistical tests. A one-way repeated measures ANOVA found no significant difference in normalized F2 at the vowel midpoint (50% of duration), $F(11, 2337) = 1.157, p = 0.312$ or in normalized F1 at the vowel midpoint, $F(11, 2337) = 1.561, p = 0.104$[7] This indicates that all groups participated in GOOSE-fronting to an equal degree.

[6] With understanding that the idea of using the White-identified group as "the norm" is both methodologically and culturally problematic, I maintain that the White-identified group represents CVS as has been described in the literature, per the discussion in Section 1.4.

[7] An ANOVA run at 25% of the vowel duration, or ntime=2, found significant differences in UW height, indicating that the vowel may begin higher for some groups than others.



(a) Korean-identifying females

(b) Vietnamese-identifying females

Figure 3: Female Californian vowel trajectories by ethnic self-identification (2).

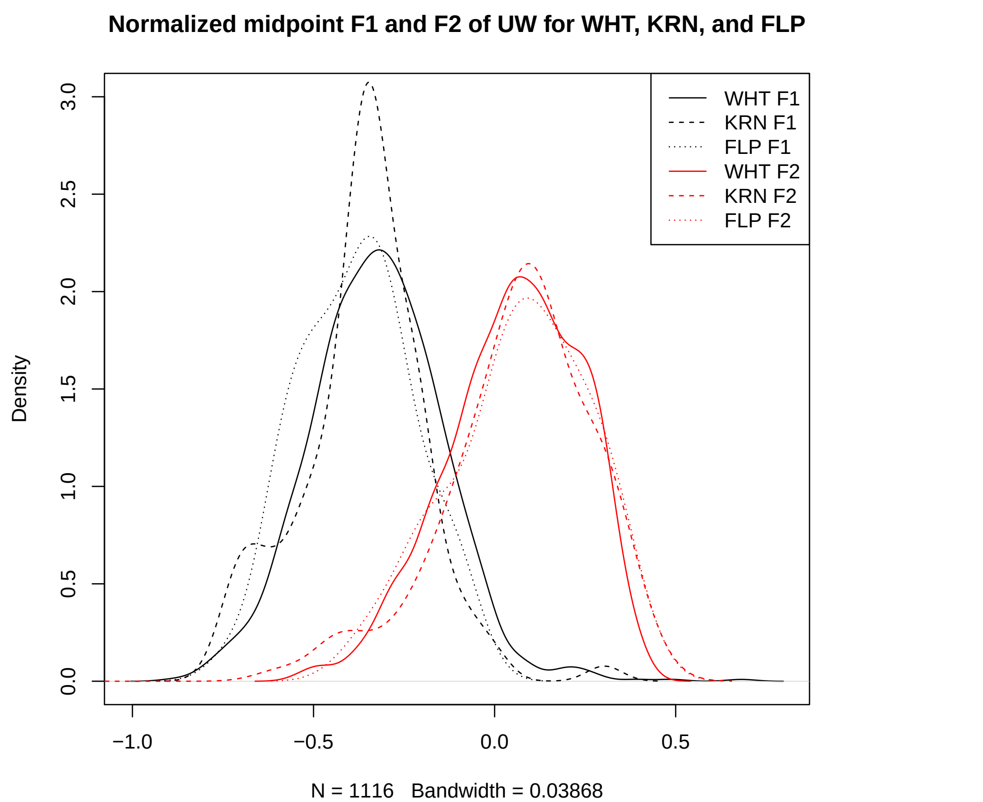


Figure 4: Density plot comparing normalized F1 (black lines) and F2 (red lines) of UW among three ethnicities. No significant difference in F1 or F2 was found.

Also observed for all speakers is the *cot-caught* merger, which can be observed in the overlap of the vowels AA and AO for all speakers.

For other vowels involved in CVS, there are differences in movement that can be observed between ethnic groups. For example, the split in the low front vowels (prenasal HAND and non-nasal TRAP) can be clearly seen in White- and Vietnamese-identifying speakers, but appears to be considerably less pronounced in Chinese- and Korean-identifying speakers.

Two separate analyses of variances of the median F2 and F1 of these groups were run; only frontness of the HAND vowel was found to vary significantly by ethnicity, $F(11, 832) = 2.16, p = 0.0148$; vowel height was not affected by ethnicity, $F(11, 832) = 0.98, p = 0.463$. All median normalized F2 values for AEN can be seen in Figure 5. A post-hoc subset ANOVA determined that the ethnicity best explained the variance in fronted-AEN when comparing the White group and the Chinese group, $F(1, 514) = 14.51, p = 0.00016$), as well as the White group and the South Asian group, $F(1, 424) = 4.08, p = 0.044$. These two groups have a less-fronted HAND vowel than the White group.

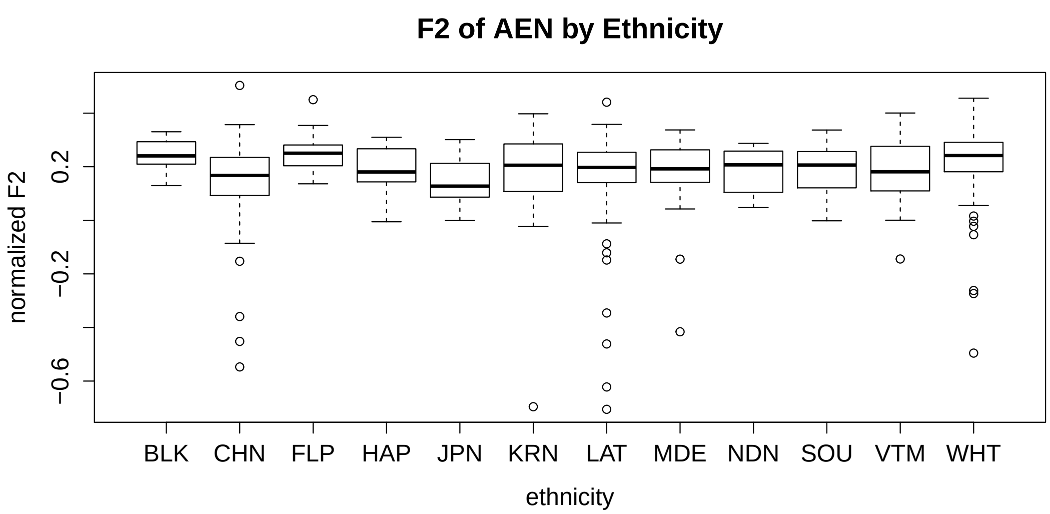


Figure 5: Box plot comparing means of F2 of AEN among all ethnicities. A significant difference was found when comparing the White group to the Chinese and South Asian groups.

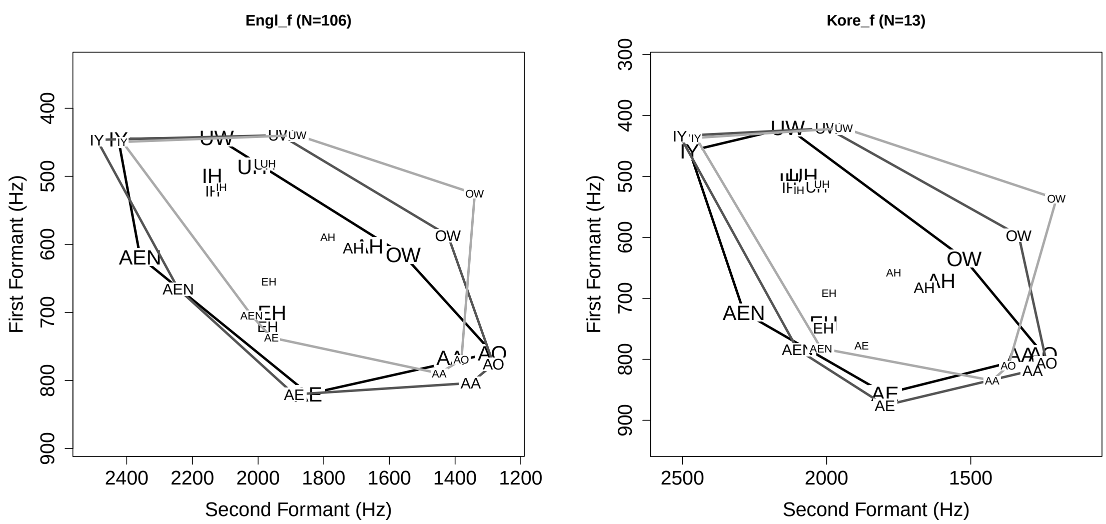
Impressionistically speaking, the backing of the KIT vowel seemed pronounced for all speakers, to the point of being merged with the fronted FOOT vowel, especially for Korean-identified speakers. A repeated measures one-way ANOVA was run on the F2 of the FOOT vowel, and ethnicity was found to be a marginally significant factor, $F(11, 900) = 1.62, p = 0.088$. Subset ANOVA post hoc tests identified ethnicity as a a significant predictor of fronted UH when comparing the White group to the Korean group, $F(1, 475) = 4.22, p =$

0.04, and the White group to the South Asian group, $F(1, 464) = 6.223, p = 0.013$. These two groups have a more fronted FOOT vowel compared to the White group.

A full table of ANOVA and post hoc analysis results can be found in appendix A.3.

3.2 Variance by Language

Figures 6a and 6b show two examples of differences between English monolinguals and Korean-English bilinguals. First of all, we would expect the vowel trajectory of Korean-English bilingual women to greatly resemble that of Korean-identified women (3a), which it does. In fact, the thirteen speakers represented in Figure 6b are exactly the same as those represented in Figure 3a, minus one Korean-identified speaker who does not speak Korean[8].



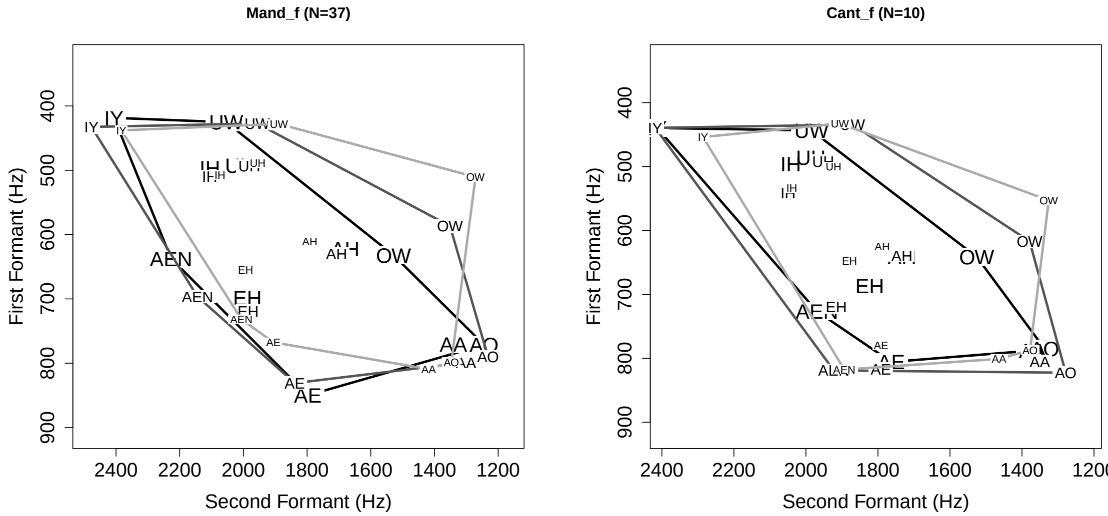
(a) English monolinguals

(b) Korean-English bilinguals

Figure 6: Female Californian vowel trajectories by language

We should not, however, assume that the English monolinguals are all White, since the possibility of, for example, Black, Japanese, or Chinese-identified English monolinguals still exists. (Conversely, the probability of an ethnic non-Korean claiming native Korean-English bilingualism is extremely low.)

[8]This was determined by comparing the anonymized speaker ID numbers from the Korean-identified participants to the Korean-English bilingual participants.



(a) Mandarin-English bilingual women

(b) Cantonese-English bilingual women

Figure 7: Female Californian vowel trajectories by language.

What, then, does analyzing vowel formant differences by native language and bilingualism tell us that ethnic identity does not? It is important to remember that there is not necessarily a one-to-one correspondence between a language and any given ethnicity. For example, people who identify as ethnically Chinese (or are forced to identify as such due to the limited choices offered on census surveys) may speak any number of languages, including Mandarin and Cantonese. But Mandarin and Cantonese, while both members of the Sinitic language family, are considerably different, especially in their phonologies. Thus, it stands to reason that a difference in vowel trajectories may be observed in Mandarin-English bilinguals versus Cantonese-English bilinguals.

Indeed, Figures 7a and 7b above display a few clear differences. The Mandarin-English bilingual females show a much larger AE-AEN split than the Cantonese-English bilingual females. This was verified by an ANOVA that found a difference in AEN F2 values by language, $F(6, 458) = 2.321, p = 0.032$ and a post hoc test that corroborated the more-fronted AEN of the Mandarin-English bilinguals compared to the Cantonese-English bilinguals, $F(1, 281) = 9.402, p = 0.0024$.

Importantly, post hoc tests showed that while Cantonese-English bilinguals did not differ significantly from English monolinguals, $F(1, 297) = 0.409, p = 0.523$, Mandarin-English bilinguals did differ significantly from English monolinguals, $F(1, 188) = 8.834, p = 0.00334$. A density plot of median F2 values for the HAND vowel can be seen in Figure 8.

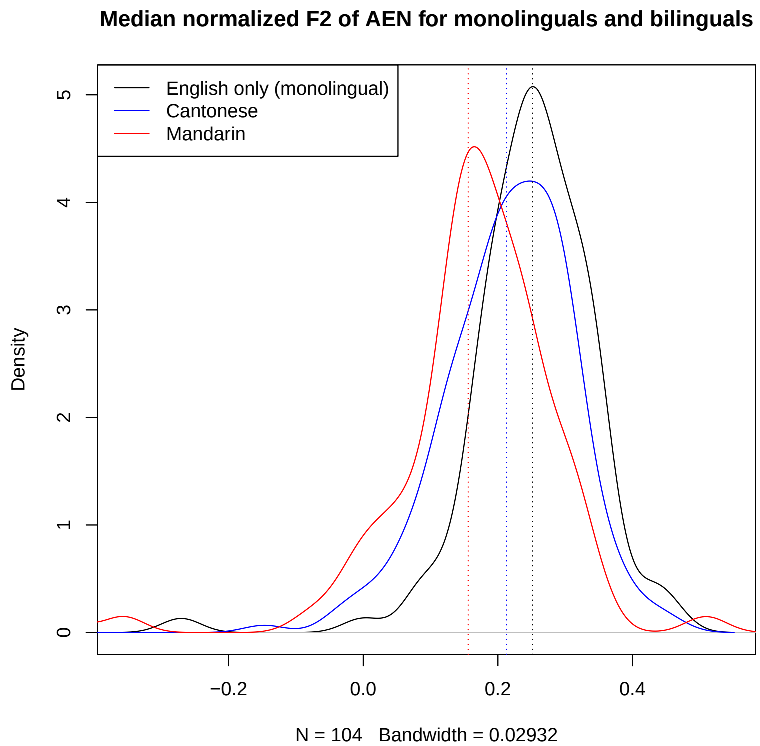


Figure 8: Density plot of median F2 values for AEN among Cantonese-English bilinguals, Mandarin-English bilinguals, and English monolinguals.

Also significant was the difference in height (but not backness) of the DRESS vowel, where Mandarin-English bilinguals' is lowered somewhat in comparison to the Cantonese-English bilinguals' DRESS vowel. An ANOVA confirmed variation in EH F1 values as an effect of language background, $F(6, 1268) = 2.35, p = 0.0292$, and a post hoc test using subset ANOVA found a marginally significant difference in vowel height when comparing Mandarin-English bilinguals and Cantonese-English bilinguals, $F(1, 771) = 2.803, p = 0.0945$.

Finally, significant results were also found when comparing Korean-English bilinguals to English monolinguals and Vietnamese-English bilinguals to English monolinguals. A full table of ANOVA results can be found in Appendix A.3.

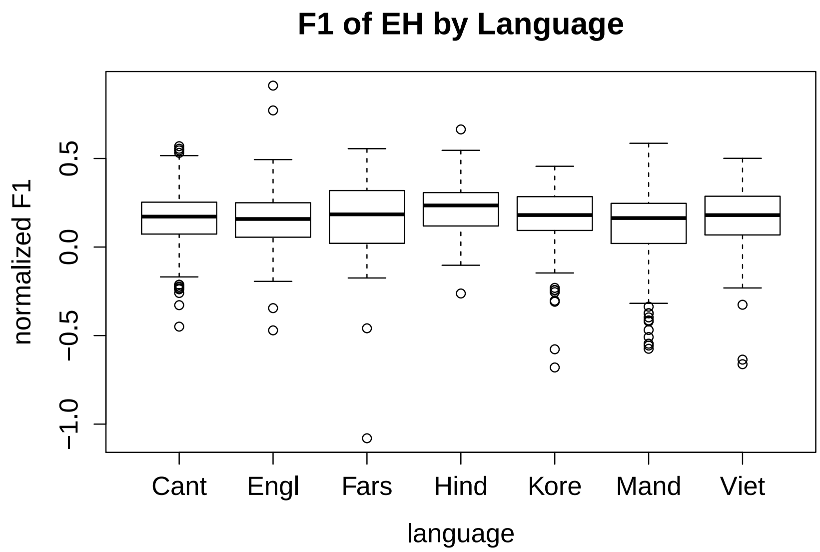


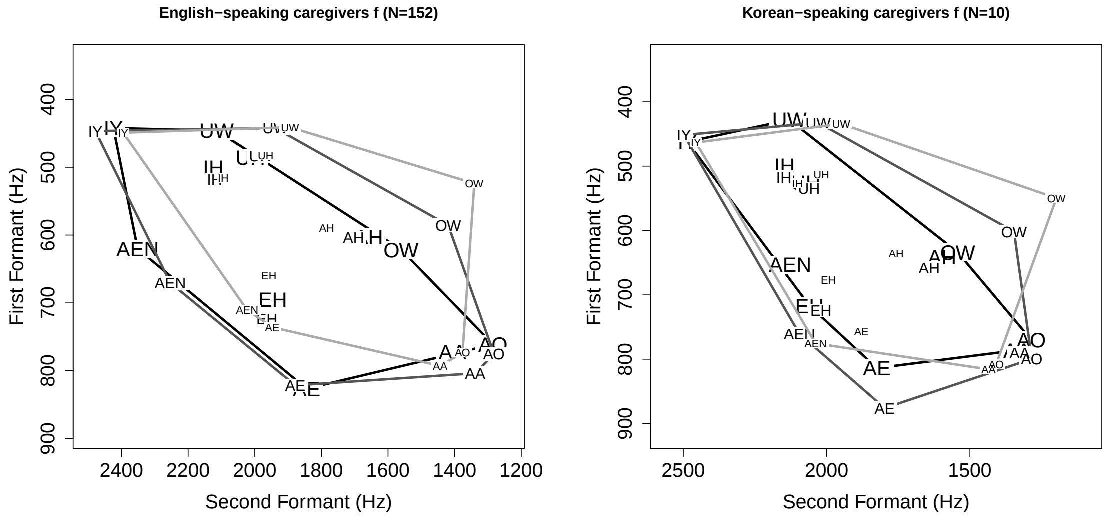
Figure 9: Box plot comparing means of F1 (height) of EH among all languages. A significant difference was found when comparing the Cantonese-English bilinguals and Mandarin-English bilinguals.

3.3 Variance by Caregiver Language

Variance in vowel trajectories as a function of the languages spoken by a speaker's two caregivers was also analyzed. We might expect the results to be quite similar to those taken from the bilingual categorizations, and indeed, Figure 10b is almost indistinguishable from Figure 6b. What look to be differences from pure observation, including less overlap in the KIT and FOOT vowels and more raising at the first midpoint of the HAND vowel in 10b, did not prove to be statistically significant differences. This is certainly logical not only to relatively small sample sizes, but also due to the overlap in data. Comparing the Korean-English bilinguals to the so-called "heritage Korean speakers" is, statistically speaking, tantamount to comparing the same exact group of people.

The theoretical issue that any statistically significant differences may point toward, should they be found, is the difference between heritage language experience and true bilingualism. Given that many children of immigrants from non-English speaking countries tend to experience attrition of their parents' language even if they are spoken to exclusively in that language from birth, it is of interest to see if that language still affects a speaker's production in the dominant language (i.e. English).

To that end, further research in this domain would need to further sub-categorize by



(a) English-speaking caregivers

(b) Korean-speaking caregivers

Figure 10: Female Californian vowel trajectories by caregiver language.

speakers whose parents' L1 was Korean (for example) but 1) do speak Korean and 2) do not speak Korean. Unfortunately, the sample size may be too small to do this for any non-English language in the Voices of Berkeley corpus, with the possible exception of Mandarin.

4 Discussion

It is quite clear that aspects of the California Vowel Shift are present in the Voices of Berkeley corpus. If the first description of CVS came from young adults in the late 1980's, then the persistence of the shifts in young adults in the present day is longitudinal evidence that this is a change in progress or, perhaps, even complete. It is also apparent that subgroups of Californian English speakers participate in CVS in different ways depending on their ethnicity or language background.

For almost all speakers in the corpus, the fronted GOOSE vowel was observed (in mostly non-coronal contexts) with slight diphthongization. The *cot-caught* merger was also easily identified in all speakers. Thus far, these findings support the hypothesis that this regional sound change is equally robust among White and non-White speakers of Californian English Hall-Lew (2009).

For front vowels, the expected observation was a generally backed and lowered DRESS vowel and a split between the vowels in TRAP and HAND. Indeed, the DRESS vowel nearly overlapped with the offglides of the diphthongized AE variants for most speakers. The HAND vowel began extremely fronted and raised, and the TRAP vowel began fairly low and backed, but across their trajectories, both vowels moved toward the DRESS vowel. However, in comparison to the White group, the HAND vowel was not as fronted for Chinese and South Asian-identifying speakers, and the DRESS vowel was somewhat less lowered for Korean-English bilinguals and Vietnamese-English bilinguals. Also, the Chinese-identifying speakers with less pronounced AEN-fronting were more likely to be bilingual speakers of Mandarin than Cantonese.

The lowered IH, in combination with a fronted and lowered UH, appeared to result in something that may be called a *kit-foot* merger. The fronting of UH was more pronounced for South Asian and Korean-identifying speakers, when compared to the White group. This particular sound change has not been documented in the literature. Anecdotal evidence, however, brings at least one salient example of it to the table: the loss of contrast in young Californians' pronunciations of *woman* and *women*, where the plural form /wɪmɪn/ (with IH) is no longer distinguishable from the singular /wʊmən/ (with UH). Further research should be done to see how far the extent of this possible merger goes: whether it is limited to certain words, is phonologically conditioned, or indexes any sociodemographic variables, et cetera.

The following sections will look specifically at the categorizations of ethnicity, participant language, and caregiver language and discuss their relevance to the results and to current theoretical issues.

4.1 How ethnicity may affect English vowel space

Hall-Lew (2009) was the first to closely analyze the fronting of back vowels in CVS in terms of ethnicity, suggesting that the change, as documented in a largely Asian neighborhood of San Francisco, originated in an older White American cohort. It was then adopted by younger White and younger Asian American speakers, but not by older Asian American speakers. This is just the first of many speculations of how race and ethnicity affect the English production of immigrant and second-generation speakers.

Perhaps the most straightforward explanation may come from social network theory. Immigrant communities may spend much more time among those of the same ethnicity than those of other ethnicities, even the dominant ethnicity (which is White, in the case of modern California and the United States). Ethnic boundaries, which have often intersected with geographical boundaries, have been identified as sources of variation for Black and Hispanic Americans (even though the former group did not recently immigrate and speaks English) in many studies since Labov (see Baugh, 1983 and Penfield and Ornstein-Galicia, 1985 for reviews).

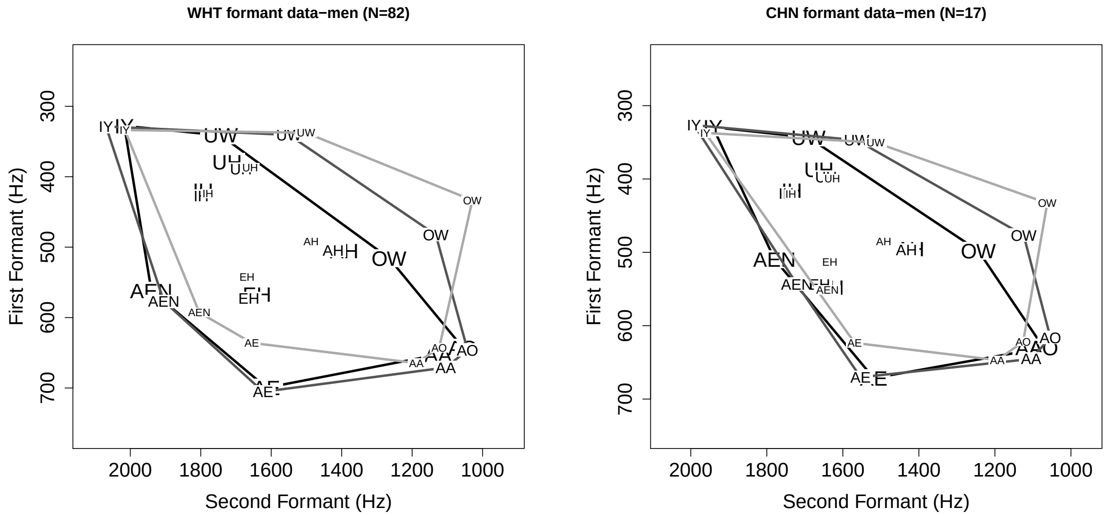
For Asian Americans, Hanna (1997) was among the first to provide evidence for differences in "Asian-sounding" voices, compared to "White-sounding" voices, where the Asian categorization was a mix of various kinds of East Asian and Southeast Asian ethnicities. Since then, sociolinguistic and sociophonetic studies have focused on specific ethnicities: Wong (2007) and Hall-Lew (2009) on Chinese Americans in San Francisco and New York, Lee (2000), Chun (2001), and Schirra (2012) on Korean Americans in Philadelphia, the Midwest, and the Pacific Northwest, and Reyes (2005) on Southeast Asian immigrant youth (Cambodian, Laotian, and Vietnamese) in their use of slang originating from AAVE, are a few examples.

However, none of these studies assumes from the start that the ethnic distinction per se is what drives the sound changes in question. It is not simply by virtue of being ethnically Korean or hanging out with other Korean American youth that a particular Korean American English speaker will acquire the characteristics that make them identifiable. Responsible studies will exercise restraint from making claims stemming from such simplism, which from the perspective of anthropology is a good practice. After all, ethnic identity is largely socially constructed. Other social factors such as class, networks (Hall-Lew, 2009), region (Wong and Hall-Lew, 2014) and in-group versus out-group ideologies (Eckert, 2008a), or historical factors such as immigration history (Chun, 2009; Hall-Lew and Starr, 2010), ties to the land (Podesva et al., 2015b), and changes in language attitudes (Wiley and Lukes, 1996), also play important roles in sound change and dialect development.

This necessarily complicates the simpler ethnic categorizations we have used until this point, although it does not mean that a uniformitarian approach is absolutely wrong. In the vein of Rickford (1986), we will draw on as many diverse theoretical ideas and models as we need in order to build the most complete framework for understanding Asian American speech.

So, in addition to network theory, we may also consider the theory of indexicality pioneered by Silverstein (2003) and Eckert (2008b). According to Eckert, the phonetic variable is not inherently connected to any particular social variable; that is to say, a raised pre-nasal AE does not "belong" in any sense to a White female Southern Californian. But variables do indicate and then mark social identities, rising through the levels of indexicality to become, somehow, the sounds that stereotypically represent such personae. One variable can even index different identities to different degrees (see for example Hall-Lew, 2005 and Podesva et al., 2015a).

Thus, any given phonetic variable may have arisen from a random innovation or from language and dialect contact (which is common in Asian American communities). Because of the unanchored nature of indexical meaning, whatever a variable may have indexed in, say, a mother tongue or in a children's schoolyard, it can now also index other identities, such as "White Californian" or "Chinese Californian", as well as convergence toward or divergence from them.



(a) White-identifying males

(b) Chinese-identifying males

Figure 11: Male Californian vowel trajectories by ethnic self-identification.

Let us take the front vowel of Chinese-identified Californians as an example. Our results from Section 3.1 indicated that the HAND vowel was less fronted for Chinese American speakers when compared to White American speakers (but specifically for those Chinese American speakers who were native bilinguals of Mandarin and English). This may be related to the apparent overlap of the HAND vowel and DRESS vowel that can be seen in Figures 11a (illustrating the expected raised AEN for White Californian men) and 11b (illustrating the overlap of AEN and EH for Chinese men).

What exactly does Figure 11 tell us? Simply that the young Chinese Californians display different qualities of low front vowels from White Californians, or that their vowel qualities are unusual for Californians. As far as AEN-fronting is an aspect of CVS, the Chinese group is not participating in this part of the vowel shift. However, other Asian groups are participating in AEN-fronting, while the Chinese group also participates in UW-fronting, EH-backing, and the *cot-caught* merger.

However, we must go further than concluding that "Chinese Californians speak English differently"[9]. This would be the kind of oversimplification that Rickford pushed against. If the Chinese-identified English speakers have been influenced by Mandarin or Cantonese,

[9] And we must also take care to examine the way we word any hypothesis or conclusion; in this case, the ethnic minority group is positioned as the Other and the White majority is assumed to be the baseline or standard. This is itself problematic for a few reasons, but I will leave that particular discussion for another time.

then we can look at the phonologies of those languages and identify possible transfer effects (see Section 4.2). We could posit that Chinese-identified Californians are lagging in the sound change that their White peers are undergoing, which would align with theories that young minorities adopt sound changes subsequently to the majority populations that advance them (Hall-Lew, 2009).

Or, we could consider that they are leading a new kind of sound change, although without any real or apparent time studies, this would be impossible to corroborate. Recall that Labov (2001) theorized that sound change from below originates in a central social group but hypothesized that immigrant communities would resist majority-led changes. What would it mean, then, if some Asian American groups were leading change (e.g. the socially dominant Chinese American community in the Sunset District of San Francisco leading sound changes as shown in Hall-Lew (2009))?

Chinese students are certainly the largest non-White ethnic group at the University of California, Berkeley. As of Fall 2015, Chinese students make up 19.5% of the new freshman class, which is twice as large as the two next largest groups (8.9% "South Asian" and 9.0% Chicano), and larger still than the next six ethnic groups combined (UCB Office of Planning and Analysis). As a part of the school's "minority majority", Chinese students may experience some degree of social capital. But of course, the Chinese-identified participants in the Voices of Berkeley project contributed their recordings before they matriculated.

On the other hand, it is also possible that Chinese Americans are adopting a variable that indexes a different social identity, such as an urban/suburban persona, alignment with Northern or Southern Californian ideology, or even alignment toward a different ethnicity. Note that the White and Chicano schoolchildren in Eckert's 2008a made use of TRAP-vowel backing to index peer in-group and out-group identity almost regardless of ethnic identity.

To take another example, Chinese and Korean-identified Californians tended to have less movement in the trajectory of the diphthongized GOOSE, TRAP, and HAND vowels (see Figures 2b and 3a), which is a similar pattern seen in speakers of Chicano English (Fought, 2003), or Californians with Mexican heritage (i.e. Chicano/Hispanic ethnic identity, possible Spanish-English bilingualism, and possible Spanish spoken in the home by caregivers).

If one takes the following findings: 1) the parallel inhibition of particular vowel shifts in speakers of Chinese, Korean, and Chicano identity, 2) the appropriation of lexical and grammatical features of AAVE by some Korean Americans, Southeast Asian Americans, and Chicano Americans who align themselves socially to Black Americans in order to index personae with social capital (Chun, 2001, 2013; Dunstan, 2010; Igoudin, 2011), and 3) the ability of a linguistic variable to traverse social boundaries through various media of cultural transmission, à la the "semiotic hitchhiking" introduced in Mendoza-Denton (2011), then it would not be unreasonable to look for causation for the correlation we find among ethnic minorities in our California corpus.

Without actual ethnographic work, perception and valuation experiments, or metalinguistic judgments, however, the range of possible indices for these variables are only hypotheses. Even so, it is important to view this data as being indicative of more than just ethnically-conditioned variation.

4.2 How bilingualism may affect English vowel space

Another important theoretical lens through which to analyze the Voices of Berkeley corpus findings is that of bilingual language acquisition. As noted in Section 3.2, ethnic identity and language do not necessarily correspond to one another. Census data may categorize Americans whose ancestors hail from disparate parts of modern China and Taiwan as all Chinese, even if they are not ethnically Han or do not all speak Mandarin. In fact, we can see that Cantonese-English bilinguals and Mandarin-English bilinguals among the female Californian subgroup have some radical differences in their vowel trajectories.

Hall-Lew (2009) notes that knowledge of foreign languages has the potential to inhibit some kinds of vowel shifts (170), if not on the individual level, then at the community level. In particular, she lays out the reasons why speakers of Cantonese or Mandarin might have very fronted GOOSE and GOAT vowels (mapping of front rounded vowels onto the English UW and OW) or, on the contrary, might experience inhibition of fronting (approximating English UW and OW without correspondence). Similar arguments for fronting inhibition are given for speakers of Tagalog and Japanese.

Our results did not show inhibition of GOOSE-fronting per se, but most subgroups of bilinguals (Mandarin-English, Cantonese-English, Korean-English, Farsi-English, and Hindi-English bilingual females, as well as Korean-English bilingual males) displayed shorter trajectories for their GOOSE vowel, indicating either monophthongization, less diphthongization, or a less fronted starting point for the diphthong[10].

Studies in bilingualism have recently focused on the idea of transfer, or L1 influence on production and perception of the L2 (see Jia et al., 2006; Chang, 2013 and Major, 2008 for a review). However, only a few of these studies have focused on vowel production or Asian language transfer. Chang et al. (2011) found that Mandarin-English bilinguals outperformed native Mandarin speakers and native English speakers in maintaining both functional and non-functional contrasts in high back vowels of both languages. Lee et al. (2006) found that early Korean-English bilinguals manifested less dispersion in formant values for unstressed English vowels (AH, IH, UH) compared to native English speakers, which was theorized as being influenced by Korean phonology.

[10]ANOVA for F2 of UW indicated a significant effect for language background, $F(6, 3841) = 5.209, p < 0.0001$, although a post hoc test indicated only three pairs of bilingual groups with significant differences: Cantonese bilinguals and English monolinguals ($d = -0.03, p = 0.01$), Cantonese bilinguals and Farsi bilinguals ($d = -0.052, p = 0.03$), and Cantonese bilinguals and Hindi bilinguals ($d = -0.078, p = 0.01$).

Although the literature is sparse, it seems to support the idea that bilingualism varies between languages, which is also simply common sense. We should expect the Englishes of Tagalog-English bilinguals and Vietnamese-English bilinguals to differ, even though they are both "Southeast Asian".

In addition, sociocultural factors attached to different languages will lead to different amounts of variance in individuals or even in communities. For example, the Cantonese-English bilinguals in the Voices of Berkeley corpus may come from families that recently immigrated from Hong Kong or from families that have been living in Chinatown-esque enclaves in California for generations. The Mandarin-English bilinguals are most likely to have come from families that recently immigrated from China or Taiwan. Due to differences in immigration that lead, directly or indirectly, to differences in class and social networks in California, the way the Cantonese-English bilinguals and the Mandarin-English bilinguals speak English may differ for reasons unrelated to the phonologies of the languages themselves.

4.3 How caregiver language may affect English vowel space

Even if a speaker is not "truly" bilingual, if they have had experience with a heritage language, that experience matters. While bilingualism has been extensively studied in the fields of psycholinguistics, phonetics, and sociolinguistics, studies on the effects of heritage language on any aspect of language production and perception are relatively new.

It has been shown already that a speaker's heritage language has notable effects on production. Childhood "overhearing" of a non-English language improves perception of the language later in life (Oh et al., 2003), and may facilitate production (in terms of accent, phonetic contrasts, and some lexical items), as well (Au et al., 2002). In addition, childhood speaking of a non-English language, even if the language is subsequently lost to attrition as the child grows up, is greatly beneficial for production and perception of the heritage language (Chang et al., 2011), though the degree of benefit can vary by language and sociocultural factors such as the speaker's childhood immersion in and current identification with the language community (Oh and Au, 2005).

However, only Chang (2013) has looked at the effects of heritage language experience and exposure on the *dominant* language (i.e. English, for his study and the present study). It found that "mesolectal" heritage language speakers of Korean, or Korean Americans who were continuously exposed to the Korean language throughout childhood but generally understand much more than they are able to speak, not only matched native Korean speakers in perception of Korean stop contrasts, but also outperformed native English speakers (with no Korean experience) in perception of *English* stop contrasts. The conclusion was that the effects of heritage language experience can extend past the domain of production and perception of the heritage language.

The consequences of this in a corpus sociophonetic study such as the current one is that caregiver language(s) as a linguistic-demographic variable is both valid and distinct from the variable of L1 and L2 in bilingual speakers. The caregiver languages that each speaker identified are their heritage languages. Knowing that exposure to a heritage language can affect perception of English, we can reason that it can affect production of English, as well. We thus might be able to observe differences between Korean-English bilingual participants and participants whose caregivers speak Korean *but who do not speak Korean themselves.*

Unfortunately, as noted in section 3.3, the data necessary for that particular analysis is currently unavailable. It would require normalization by gender of the current subgroup of speakers with Korean-speaking caregivers, and then a split between fluent and non-fluent ("acrolectal" versus "basilectal"; see Polinsky and Kagan, 2007) members of that subgroup. Even then, the numbers may be too low for reliable analysis (see footnotes in Sections 2.1.2 and 2.1.3).

4.4 Other social factors

Because of the nature of data collection for the Voices of Berkeley project, a few additional experimental and social factors should be considered, including imagined audience, experimental control, and stereotypes of the institution.

The first draws on ideas of persona style Eckert (2008b) and audience design (Bell, 1984). We must take into account that a person's speech can and will vary depending on the intended audience of their speech event. Generally, experimental research, even in sociolinguistics, attempts as best it can to negate the extraneous factors that might skew results: this includes using the same laboratory equipment and stimuli, standardizing scripts for researchers when interacting with participants, and very carefully controlling all potential social cues.

However, the Voices of Berkeley corpus did not control any aspect of data collection other than the script used to run the applet. Participants may have recorded in their home, in a busy cafe, or even at a party with friends present. Some may have felt a need to present their "best" self (or voice), knowing that their recording could be potentially heard – and possibly judged – by hundreds of other people. Others may have produced formal "reading-style" recordings or made a particular effort to put on a joking or stereotypical accent (as noted in Section 4.2).

The recordings were screened only for quality, not persona style. It is assumed that the few participants who used a style that was different than usual would be washed out as noise by the sheer number of participants. However, it is still worth noting that any given speaker may have desired, even subconsciously, to present themselves in a way that would lend focus to an important personal identity. From there, it is possible that a group of speakers could do this, and that the important identity may have been race.

Recall from Section 4.1 that Berkeley has a very high percentage of Asian Americans, particularly Chinese Americans, in its student body. Among the University of California schools, and indeed throughout the entire country, UCB has a reputation not only for being challenging and top-tier, but also for being an "Asian" school (referenced by clever and stupid nicknames such as "University of Chinese Brainiacs" or "University of China's Best"). Incoming students knowing that they were going to attend the "University of Competitive Bastards" and find themselves in an ethnic and academic environment quite different from the rest of the state and country could very well have accounted for this as part of their "audience" when presenting themselves, especially if they were Chinese.

Since Labov's Martha's Vineyard study, it has been observed that phonetic differences between social groups can become stronger as the group fights to maintain its identity (Labov, 1963; Bourhis and Giles, 1977; Babel, 2010). A future study could observe attitudes of Californians toward people of Chinese ethnicity and search for markers of social valuation in their speech.

5 Conclusion

The results of this study confirm the California Vowel Shift among young Californians across geographic, ethnic, and gender lines. It is the first known study to use a large corpus drawn from such diverse demographics to corroborate the original findings of Hinton et al. (1987). Of specific interest was the interaction between ethnicity and variance in degree of shift for vowel shifts such as UW-fronting, EH-backing, the TRAP-HAND split, and the KIT-FOOT merger. In particular, while all of the Asian subgroups participate to some degree in CVS, they do not participate in the vowel shift equally. The degree to which an individual will participate in one part of CVS depends on ethnicity as well as language background.

Because most (though not all) Asian American communities in California have a recent history of immigration, or wave-like patterns in their growth in the state, we can interpret inter-ethnic variance through various theories such as social network theory and communication norms (Gallois and Callan, 1991; Auer et al., 2005), because the relationship between the host community and the immigrant community matters. We can also bring in theories of social identity (Eckert, 2008b) and indexicality to postulate how speakers use certain variables beyond the scope of their ethnicity.

Lastly, differences in variation when categorizing by ethnicity, language background, and heritage language background indicate that the mapping of a linguistic variable to one of the three sociolinguistic factors does not necessitate that it carries over to the other two;

all three factors must be considered separately before they are evaluated together.

Future studies, as mentioned previously, may look more carefully at the sociodemographics of the Voices of Berkeley corpus, particularly by geographic location. Because there are enough Mandarin-English bilinguals and Chinese-identified speakers, this subgroup may be further divided by county or by region (Northern versus Southern California, or urban/suburban versus rural) to allow the valuations found in Bucholtz et al. (2007, 2008) to emerge, if they exist. It would also be interesting to see if the patterning of Asian Americans in the large urban center of Los Angeles follows those of Chicano Americans, which make up a large "minority majority" there, and if "country ideologies" in CVS patterns who up for Asian Americans in rural areas.

Of course, the potential for phonetic analysis does not stop at vowel quality. Other acoustic measurements such as voice onset time, stop closure duration, /l/ quality, sibilant frequency, and even suprasegmental pheneomena such as creaky voice or intonation can be harnessed and compared to the current sociophonetic literature of American or Californian English.

In addition, with the recordings from the corpus, many perception experiments that investigate language attitudes and metalinguistic judgments can be done. A dialect identification task by Newman and Wu (2011) found evidence that a lowered DRESS vowel was a marker of an "Asian-sounding" voice, even though the Asian speakers used in the experiment were a mix of Chinese and Korean ethnicities. The extent to which any given voice is identifiable by casual listeners as a certain ethnicity, and which variables index this, would be a rich avenue for future study.

A Appendices

A.1 Ethnic identity labels in Voices of Berkeley corpus

Ethnicity Label	Reported Identity	Ethnicity Label	Reported Identity
Korean (KRN)	Korean	Middle Eastern (MDE)	Afghan
	Korean-American		Middle Eastern
Chinese (CHN)	Chinese		Pakistani
	Chinese-American		East Indian
	Taiwanese		Parsi
	Taiwanese-American		Persian
Filipino (FLP)	Filipino	Southeast Asian (SEA)	Indonesian
	Philipino		Malaysian
South Asian (SOU)	Gujurati		Thai
	Bengali Indian	Japanese (JPN)	Japanese
	Indian		Japanese American
	North Indian	Vietnamese (VTM)	Vietnamese
	Punjabi	White (WHT)	Caucasian
	South Asian		Caucasian/White
	South East Indian		White
	South Indian		

Table 5: Reported ethnicities of Voices of Berkely corpus participants and their ethnic categorizations. Ethnicities not categorized for this study were listed as "NonAsian" (and non-White) and included: American Indian or Alaska Native, Armenian, Black Latina, Black or Afro-American, Chicano or Mexican-American, Hispanic, Latino or Other Hispanic, Mexican, and Peruvian. The "NonAsian" category also included labels such as Biracial, Mixed, Multiracial, and any iteration of multiple ethnicities, such as "Taiwanese and Greek". Labels such as "declined to state", "other", and one clever "only myself" were also included in the "NonAsian" category. Lastly, the "NonAsian" category included participants who entered "Asian", "Asian American", or "Other Asian", due to their infrequency (n=15) and the impossibility of determining their exact ethnicity.

A.2 Production stimuli

1. Go Bears!
   OW EH

2. Dawn found it odd that Judd did a handstand.
   AO AW IH AA AH AEN-AEN

3. She had your dark suit in greasy wash water all year.
   IY AE UH AA UW IH IY AA AO AO IY

4. Who said you should hold such an awkward pose?
   UW EH UW UH OW AH AA OW

5. Don was awed by the hat rack.
   AA AO AY AE AE

6. This wheel's red spokes show why mud is no boon.
   IH IY EH OW OW AY AH OW UW

A.3 ANOVA Results Tables

The results of post hoc tests of ANOVA are reported here. These tests were run on the gender-normalized data and may also include ethnicities with significant results that were not reported before, including BLK (Black), LAT (Latina/o), HAP (Hapa), and NDN (Indigenous American).

A.3.1 UW formant values by ethnicity

A one-way repeated measures ANOVA was run on the median F1 and F2 values of each speaker(id)'s UW vowel, except where indicated.

F2 (backness)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.54	0.04936	1.157	0.312
Residuals	2337	99.73	0.04268		
F1 (height)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.62	0.05662	1.561	0.104
Residuals	2337	84.75	0.03627		
F1 (height)	measured at ntime=2	(25%)			
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.77	0.06967	2.094	0.0179*
Residuals	2341	77.90	0.03328		
F1 (height)	measured at ntime=2	(25%)	subset CHN, JPN		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.132	0.1323	4.201	0.0411*
Residuals	350	11.024	0.0315		
F1 (height)	measured at ntime=2	(25%)	subset CHN, VTM		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.175	0.17465	4.653	0.0316*
Residuals	378	14.189	0.03754		
F1 (height)	measured at ntime=2	(25%)	subset WHT, VTM		
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.27	0.27238	8.088	0.00453**
Residuals	1179	39.70	0.03368		

A.3.2 AEN formant values by ethnicity

A one-way repeated measures ANOVA was run on the median F1 and F2 values of each speaker(id)'s AEN vowel. A significant difference was reported when comparing F2 of White and Chinese speakers and when comparing F2 of White and South Asian speakers.

F1 (height)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.361	0.03286	0.98	0.463
Residuals	832	27.908	0.03354		
F2 (backness)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.345	0.03132	2.16	0.0148*
Residuals	832	12.066	0.01450		
F2 (backness)	subset WHT, CHN				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.169	0.16906	14.51	0.000157***
Residuals	514	5.991	0.01166		
F2 (backness)	subset WHT, SOU				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.037	0.03728	4.08	0.044*
Residuals	424	3.874	0.00914		

A.3.3 UH F2 by ethnicity

A one-way repeated measures ANOVA was run on the median F2 values of each speaker(id)'s UH vowel. Significant differences were found when comparing White speakers with Korean and South Asian speakers.

F2 (backness)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	11	0.154	0.013962	1.62	0.088(*)
Residuals	900	7.756	0.008618		
F2 (backness)	subset WHT, KRN				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.041	0.04122	4.222	0.0404*
Residuals	475	4.637	0.00976		
F2 (backness)	subset WHT, SOU				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
ethn	1	0.0344	0.03440	6.223	0.013*
Residuals	464	2.5649	0.00553		

A.3.4 AEN F2 by language

A one-way repeated measures ANOVA was run on the median F2 values of each speaker(id)'s AEN vowel. Significant differences were reported when comparing Cantonese-English bilinguals to Mandarin-English bilinguals, as well as Mandarin-English bilinguals to English monolinguals.

F2 (backness)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	6	0.209	0.03481	2.321	0.0322*
Residuals	458	6.869	0.01500		
F2 (backness)	subset Cant, Mand				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.138	0.13797	9.402	0.00238**
Residuals	281	4.123	0.01467		
F2 (backness)	subset Cant, Engl				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.0043	0.004265	0.409	0.523
Residuals	297	3.0935	0.010416		
F2 (backness)	subset Mand, Engl				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.1314	0.13145	8.834	0.00334**
Residuals	188	2.7975	0.01488		

A.3.5 EH formant values by language

A one-way repeated measures ANOVA was run on the median F1 and F2 values of each speaker(id)'s EH vowel.

F2 (backness)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	6	0.125	0.02078	1.549	0.159
Residuals	1268	17.013	0.01342		
F1 (height)					
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	6	0.42	0.07080	2.35	0.0292*
Residuals	1268	38.21	0.03013		
F1 (height)	subset Cant, Mand				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.077	0.07727	2.803	0.0945(*)
Residuals	771	21.253	0.02756		
F1 (height)	subset Engl, Kore				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.095	0.09481	3.518	0.0615(*)
Residuals	376	10.132	0.02695		
F1 (height)	subset Engl, Viet				
	Df	Sum Sq	Mean Sq	F value	Pr(>F)
lang	1	0.096	0.09615	3.45	0.0642(*)
Residuals	321	8.946	0.02787		

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