

Social and Personality Variables in Compensation for Altered Auditory Feedback

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Abstract

Current speech motor control theories claim that human speech production is highly dependent on the interaction between two types of feedback: acoustic (from the auditory cortex) and somatosensory (from the vocal tract configuration of articulators, laryngeal and tongue mechanoreceptors). One strategy in studying the relationship between auditory and somatosensory feedback is to conduct laboratory experiments in which naïve subjects' auditory feedback is being gradually altered and the resulting speech production is observed. Most subjects react to this alteration by compensating for the manipulation. Although most subjects counteract the experimental feedback manipulation, many studies have found large variability in the degree of compensation, with some subjects failing to compensate at all.

For this study, it was hypothesized that the unexplained variability in compensatory behavior may be due to independent variables related to social or personality factors that independently affect compensation for altered auditory feedback. Forty-six naïve native Californian English speakers, with fronted /u/ vowel regions, were subjected to the gradual lowering of the F2 of their /u/ vowels in an altered auditory feedback speaking task. After the experiment, subjects filled out self-report questionnaires measuring their self-identification as Californians and a number of cognitive processing styles. Although California identity was not correlated with the amount of compensation, two significant and independent negative correlations were discovered: 1) the less empowered subjects felt, the more they compensated; 2) the less fronted their /u/ baseline vowel regions were, the more they compensated. These results suggest that research on speech motor control, and arguably on speech processing in general, could be expanded to include a sociophonetic approach that seems to help account for individual variability. Furthermore, these findings warrant an in-depth investigation on the effect of empowerment on speech processing.

Introduction

Hypothesizing that human speech emerged and developed as a means of social interaction and collaboration, Tomasello (2008, p. 2-3) claims that a preexisting social-cognitive and social-motivational infrastructure of shared intentionality (joint goals, joint intentions, mutual knowledge/common ground, shared beliefs-all in a context of cooperative motives of sharing and helping) has served as a psychological platform for the emergence of verbal communication. Similarly, the Cooperative Principle which underlies the Gricean maxims (Grice, 1975) assumes interlocutor interdependence in pursuit of a common conversational goal and places linguistic communication in a framework of broader social interactions.

The Communication Accommodation Theory (Giles et al., 1973; Coupland & Giles, 1988) demonstrates another link between the study of Linguistics and Social Psychology. According to Communication Accommodation Theory (CAT), interlocutors consciously or automatically

(Babel, 2009) adjust their speech style as a strategy to “manipulate psychological distance”. When seeking to decrease their psychological distance from each other, interlocutors converge their speech to their interlocutors’ and vice versa, when they want to distance themselves psychologically, they diverge their speech to become less alike.

A body of sociophonetic literature points to speakers’ long-term and situational ability to chose between several available language styles as a means to indicate identification with a particular national ethnicity (Bourhis & Giles, 1977), regional identity (Labov, 1963), class (Labov, 1966; Eckert, 1989), race (Babel, 2009; Mesthrie, 2010), or persona (Podesva, 2007). If social interaction variables can weigh in on speakers’ preference of one linguistic alternative over another, it is to be presumed that social and personality variables should be investigated especially in those areas of speech perception and production where it is not yet clear what facilitates or inhibits competing speech processing mechanisms.

Background

One debated aspect of speech perception and production that has been researched solely through the perspectives of Phonetics and neuroscience is the effect of acoustic (from the auditory cortex) and somatosensory (from the vocal tract configuration of articulators, laryngeal and tongue mechanoreceptors) feedback on speech production. A traditional speech motor control theory (Perkell et al., 1997) claims that speakers acquire an “internal model” that pairs motor programming of articulation with sound output. Thus, “motor programming for the production of speech segments is based on acoustic goals” (p.247). Auditory feedback helps create this model during speech acquisition and then, in real time speech, monitors production. In the process of monitoring, new acoustic feedback is constantly compared to the internal model of stored acoustic goals and if a discrepancy is detected production is adjusted to match the targets. A competing theory (Tremblay, Shiller, & Ostry, 2003) provides evidence that it is not acoustic but somatosensory goals that drive speech production. From their research on jaw somatosensory feedback, Tremblay et al. postulate that somatosensory feedback monitors vocal tract configurations of the articulators and compares them to the ones acquired in one’s lifetime. Like in the alternative model, detected discrepancies are corrected, but independently of the auditory feedback.

A more recent, alternative finding (Katseff & Houde, 2008) builds on the above stated speech control theories and concludes that feedback from both auditory and somatosensory sources plays a role in speech (vowel) monitoring. Auditory feedback is more important when discrepancies between acoustic and somatosensory feedback are small, and vice versa, for large incongruities between auditory and somatosensory feedback, somatosensory feedback dominates. An interacting relationship between the two feedback types for the control of voice fundamental frequency (a.k.a. pitch and F0) is also represented in Larson et al.’s study (2008). When somatosensory feedback is absent or unreliable, auditory feedback is upweighted.

Compensation for Altered Auditory (or Somatosensory) Feedback

Evidence for these recent findings is almost uniformly collected through very similar experimental procedures: Auditory or somatosensory feedback (or the combination of both) of naïve subjects are gradually altered while they are producing (reading aloud or whispering) vowels (in monosyllabic CVC words) and it is observed how they react. For most of the subjects, it is assumed that one of their feedback mechanisms detects a discrepancy between their internal

acoustic or somatosensory targets and their immediate feedback. As a corrective, compensatory strategy, participants subsequently change their production towards the opposite direction of the shifted feedback. This phenomenon is informally referred to as compensation for altered auditory (or somatosensory) feedback (Houde & Jordan, 1998; 2002; Jones & Munhall 2000; Tremblay et al., 2003; Purcell & Munhall, 2006a; Katseff & Houde, 2008; Katseff et al., 2010a; 2010b). The most commonly manipulated aspects of vowel production are pitch (fundamental frequency, F0) and vowel quality (F1 and F2 formants). Subjects' vowel inventory (baseline) is recorded before the manipulation and during the maximum manipulation plateau (after the gradual shift to maximum shift level). To obtain a measureable percent of compensation, the mean baseline values are subtracted from the mean shift plateau values. For example (Katseff & Houde, 2008): Naïve subjects read the word "head" (/hɛd/) from a computer screen while wearing a headset whose earphones and microphone are connected to a computer. They can hear themselves talk in real time and their auditory feedback primarily comes from their earphones. Unbeknownst to them, after a number of trials without manipulation, a formant re-synthesis program (Houde & Jordan, 2002) quickly analyzes their speech, increases their F1 frequencies in small increments of 3 or 5Hz, re-synthesizes, and feeds back the signal to the earphones. The altered feedback is played back undetectably fast (12ms) and somewhat authentically sounding. After several tens of trials of gradual shift, the feedback is ramped up to a maximum of 150Hz above each vowel's production and held at a plateau of another several tens of trials. If a given subject starts his¹ production at his average /ɛ/ baseline F1 of ~ 600Hz, he would eventually hear himself pronouncing an F1 of 750Hz, which often sounds like /æ/. Ideally, he would compensate by lowering his F1 and producing his intended /ɛ/ more like an /ɪ/, decreasing his F1 to ~ 450Hz. If he were to produce an F1 of 450Hz, the formant shift would make his F1 sound like his expected 600Hz. The situation where a feedback shift of +150Hz results in a production change of -150Hz is considered 100% compensation.

Variability in Degree of Compensation

While there are several conflicting views of the relative importance of auditory and somatosensory feedback, or their interaction, there is a recurring theme among most scientists in the field: there is a great variability in the way people compensate for abnormal auditory feedback. Many of the studies quoted above acknowledge that there is a sizeable minority of subjects who behave unpredictably by wandering around their baseline, not compensating at all, or even following the manipulation (Katseff et al. 2010a; 2010b; Houde & Jordan, 1998; 2002; Purcell & Munhall, 2006a; 2006b; Katseff & Houde, 2008). Some studies provide several possible explanations, but as a rule, poor compensators are uniformly excluded from the results. Below are offered some speculations:

- Although subjects were interviewed at the end of the experiment and they report not to have perceived the manipulation, it is possible that some of them noticed it and consciously restricted their production (Houde & Jordan, 2002)
- The fidelity of synthesized speech fed back was not good enough for some subjects (Houde & Jordan, 2002)
- Participants have "natural tendencies" to rely on auditory feedback to various degrees (Houde & Jordan, 2002)

¹ Katseff used a male subject population because automatic, real-time extraction of formants in female speech is error-prone for the current version of the speech analysis software.

- Poor compensators exhibit selective adaptation to speech perception (Houde & Jordan, 2002)
- Individual differences in compensation may be due to selective weighting of the two types of feedback. The poor compensator's increased reliance on somatosensory feedback may prevent them to be strongly influenced by the auditory feedback. (Purcell & Munhall, 2006b)
- Amount of compensation may be a function of the size of a particular vowel's baseline. Compensation (in the F1 dimension) will be significant as long as it is within or not far from one's vowel baseline region (Katseff & Houde, 2008). Katseff et al. (2010b) confirm that also for the F2 dimension. They examine whether compensation would be smaller for vowels with more salient lip and palatal somatosensory feedback because of increased weighting of somatosensory over auditory feedback. If lip and palatal somatosensory feedback is most salient for /u/, less salient for /ε/, and least for /Λ/, then amount of compensation should be greatest for /Λ/, less for /ε/, and least for /u/.

To test that claim they shifted up (increased) the second formant of these three vowels by 250 Hz and observed the resultant change in F2 production. This claim was not supported by their data. Instead, they found the greatest compensation to occur for the vowel /u/ that has the most salient lip and palatal somatosensory feedback. They suggest that /u/ exhibits greatest degree of compensation because California English /u/ has a larger baseline region than /ε/ and /Λ/. They did not keep track of their subjects' dialects but it is safe to assume that the majority of their participants were speaking Californian dialect to various degrees. Their study was conducted in UC Berkeley's Phonology lab. Still, there was a significant minority of "bad compensators" who were presumably Californians with large /u/ vowel regions.

Broad Hypothesis

The absence of a conclusive explanation for the unpredictability in compensation response from the perspective of Phonetics and neuroscience presents an opportunity to research this phenomenon taking a sociophonetic approach. There seem to be two competing alternatives for speakers to choose from: to rely more on auditory (ignore somatosensory) feedback and thus, to compensate more, or to rely more on somatosensory (ignore auditory) feedback and to resist the manipulation. I hypothesize that the unexplained variability in compensatory behavior may be due to independent variables related to social or personality factors that independently affect one feedback or the other and thus, enhance or suppresses compensation.

Rationale

Below, I will broadly discuss the rationale for my experimental design and which social and personality variables is this design able to test for.

As reviewed above, Katseff & Houde's findings (2008) suggest that a "good" amount of compensation is dependent on auditory feedback and unrestrained by somatosensory feedback as long as it is within or near the vowel's baseline region. This is also confirmed by Katseff et al.'s experimentation with /u/, /ε/, and /Λ/ vowels (2010b). They claim that compensation for /u/ was larger because its baseline region is larger for their (presumably) Californian subjects. The researchers shifted up (increased) F2 by 250Hz and observed that most subjects compensated almost completely, staying close to or within their baseline range. Yet, some did not exhibit a great amount of compensation.

These findings make the /u/ vowel a good candidate for investigating social and personality variables through an experimental design similar to Katseff et al.'s. In the absence of restraint from somatosensory feedback, social and personality variables could be held accountable for possible variance in compensation.

Social Variable: Attitude/Self-identification with one's native region (California /u/)

It has been widely researched and accepted that Western American English and more specifically, California speakers have a fronted /u/ vowel region (Hagiwara, 1995; Clopper, 2004; Clopper et al., 2005; Labov et al., 2006). In addition to fronting, these studies indicate a generally widely expanded /u/ vowel space with great individual variability stretching from as little as 1000Hz to as much as 1700Hz. It is also reported that, with the exception of the Southern American English dialect, the rest of the American English dialects have a significantly backed /u/ vowel region spanning from ~ 800Hz to ~1200-1300 (Hillenbrand et al., 1995; Clopper, 2004; Clopper et al., 2005; Labov et al., 2006).

Research on perceptual categorization of American English dialects finds that naïve listeners are able to differentiate American English dialects using various phonetic cues. While not salient, one of these perceptual cues is /u/ backness. Various free and forced categorization tasks provide some evidence that naïve listeners appear to have some rough phonological knowledge of dialects according to which they are able to categorize American dialects into 3 robust dialect regions, and with less precision into 6 smaller areas of American English (Clopper & Pisoni, 2004; Clopper, 2004). These studies are conducted predominantly with listeners from Indiana. Therefore, it is less likely that California listeners would perceptually categorize dialects into the exact same regions because of their geographical distance from the rest of the major population areas. Proximity of geographical location plays a role in perceptual similarity of dialects. The closer two dialects are the more alike they seem to appear (Clopper, 2004). However, it may be reasonably assumed that California speakers would have some ability to distinguish non-Californian dialects based on phonetic cues. In Fought's (2002) study on "California students' perceptions of, you know, regions and dialects", college age Californians demonstrated their categorical knowledge of US dialect regions by drawing dialect boundaries on non-labeled maps of the 48 contiguous states. Even though her study is not sociophonetic and does not directly show that Californians can acoustically differentiate dialects like "Hoosiers" can (Clopper, 2004), it suggests that naïve listeners are aware of a number of American dialects.

Based on the studies above, I am assuming that

- College age California English speakers have fronted /u/
- Other dialects where the majority of the US population is concentrated (with the exception of the US South) have backed /u/
- California speakers have some knowledge about other US English dialects
- California speakers would be able to perceive and attribute some phonetic cues to different dialects, or at least would generally recognize phonetic cues that sound unlike their own Californian dialect and label them "non-Californian"
- California speakers would perceive and categorize backed /u/ as a feature of non-Californian dialect

Labov's classic study "The Social Motivation for Sound Change" (1963) introduces the concept that the choice of one phonetic feature over another may indicate identification with a regional

identity. In his study, he describes that the more residents of Martha's Vineyard consider themselves to be true Vineyarders and want to be perceived as such, the more they centralize the first element of their diphthongs /a¹/ and /a⁰/.

That the vowel /u/ can be marked with social meaning is exemplified in a study recently conducted in post-apartheid South Africa (Mesthrie, 2010). The fall of the apartheid regime initiated the desegregation of "once tightly controlled social networks of young people of middle-class background" as observed in a recent sound change. Young middle class Black South Africans who until recently had a characteristic backed /u/ are now increasingly fronting their /u/ production as an adoption of the prestige norm of the White middle class. Furthermore, Fought (1999) observes /u/ fronting in the speech of young California Chicanos. She hypothesizes that they front their /u/ vowels as a strategy to emphasize peripheral identification with gang membership.

Hypothesis (with Respect to Attitude/ Self-identification with California)

Based on the studies above, the following experimental design was deemed best suited to explain the wide variability in compensation for altered auditory feedback as an effect of a social variable:

California speakers would be subjected to the previously mentioned procedure in which, unbeknownst to them, their auditory feedback is gradually altered. In this study, the second formant (F2) of their /u/ vowel would be shifted down (reduced) by 300Hz and as an effect they will perceive themselves to pronounce a significantly backed /u/. The prediction is that when they hear themselves producing a non-Californian phonetic feature (a backed /u/), they might feel that their aspect of regional (Californian) identity is threatened. The more they consider themselves to be Californian and implicitly want to be perceived as such, the more they would compensate and thus, oppose the manipulation that presents them with an implicit situational choice: to maintain or give up their California self-identification.

This design would also approximate another classic study by Bourhis & Giles (1977) that documents a case of accent divergence from the perspective of the Communication Accommodation Theory (CAT). In an experimental setting, the English speech of Welsh participants was observed before and after a confederate made derisive comments about the imminent demise of the Welsh language. The subjects markedly reacted to the derisive comments by changing their English accent to sound more Welsh-like and less like Received Pronunciation British. The authors interpret this speech adjustment as divergence in the framework of CAT. Since, in another study, language is found to be a very important dimension of Welsh identity (Giles et al., 1977), it is assumed that this subject pool felt that an important aspect of their social identity was threatened. Social identity is "that part of the individuals' self-concept which derives from their knowledge of their membership of a social group (or groups) together with the value and emotional significance of that membership" (Tajfel 1981, p. 255). I hypothesize that those subjects who place a higher value and emotional significance on California group membership would feel that their social identity is threatened. This would cause them to distance themselves and diverge from the threatening non-Californian dialect. To measure subjects' self-identification and attitudes towards their native state of California, a 20-item self-report questionnaire (attached in appendix) was devised following guidelines on formatting of paper-based survey questionnaires (Fanning, 2005).

Personality Variables: Autism, Self-Monitoring, Impulsivity, Power, Big Five Personality Traits

As broadly hypothesized, a multitude of personality factors that represent different cognitive styles may present “third variable problems” and may be affecting people’s responses to altered feedback. Some personality factors with specific relevance to the phenomenon of compensation for altered auditory feedback are proposed below. In addition, some standardized tests were considered as a means to control for these possible interfering variables

Autism

“Autism is defined in terms of abnormalities in social and communication development, in the presence of marked repetitive behavior and limited imagination” (APA, 1994). Baron-Cohen (1995) claims that autism is not a categorical condition, but a quantitative one. People differ in the extent to which they exhibit autistic traits. Arguably, Asperger Syndrome (AS) lies on the continuum boundary between autism and normality.

In his recent paper, Yu (2010) discovers that autistic traits may play a role in sound change driven by misperception (see Ohala, 1993 for a review). Listeners who misperceive speakers restore what they have heard relying on available context. This phenomenon is called Perceptual Compensation (not to be confused with the topic of this paper, Compensation for Altered Auditory Feedback). When they fail to properly compensate, they reinterpret the erroneous feedback to the best their auditory feedback allows them and initiate sound change. Yu quotes research on Autism that has provided evidence for enhanced perceptual functioning in people with autistic traits. Autistic people have superior perceptual abilities for low level (simple) visual and auditory identification, but in comparison to non-autistic people, perform poorly on complex perceptual tasks (Mottron et al., 2006). Using a standardized Autistic-Spectrum Quotient (AQ) (Baron-Cohen et al., 2001), Yu finds a significant positive correlation between Autism traits and Perceptual Compensation. He proposes that less autistic people have an inherent perceptual disadvantage and thus, would be more inclined to systematically initiate sound change. He further extrapolates that women, as a group are better suited to drive sound change because they exhibit statistically less autistic traits than men (Baron-Cohen et al., 2001).

Hypothesis

Enhanced auditory functioning in people with autistic traits, specifically their advantage at simple auditory tasks like identification of pure tones, etc. (Samson et al., 2006), would make them more sensitive to simple acoustic cues like the ones used in the current study. Paying more attention to auditory feedback may possibly outweigh their somatosensory feedback, and allow them to compensate more in the feedback alteration experiment. Thus, a test measuring autistic traits (Baron-Cohen et al., 2001) is warranted in this study.

Self-Monitoring

People strive to express and present themselves appropriately in social situations to different degrees (Snyder, 1974). Those driven by a greater need for social approval, tend to be especially sensitive to their situational behavior. They pay extra attention to “the expression and self-presentation of others and use these cues as guidelines for monitoring and managing their own self-presentation and expressive behavior”. On the contrary, those with lesser need for social approval care less about the situational appropriateness of their conduct. Hence, they focus less on other people’s conduct and accordingly, are less likely to monitor and control the

appropriateness of their demeanor in different social situations. A self-report questionnaire developed by Snyder (1974) categorizes participants on a continuum of self-monitoring.

Hypothesis

With respect to this study, it seems reasonable to extrapolate that people who score low on self-monitoring would be less attentive to their auditory feedback, downweight it, and thus, compensate less. And vice versa, those high on self-monitoring should be more sensitive to their auditory feedback, upweight it, and compensate more.

Impulsivity

Impulsivity, as defined by Patton et al. (1995) can be best understood when subdivided into three components:

- Motor Impulsivity is “acting without thinking”. It is also referred to as Response Inhibition Deficit (Chamberlain & Sahakian, 2007)
- Attentional Impulsiveness is “making quick cognitive decisions and inability to focus attention or concentrate”
- Nonplanning Impulsivity is defined as “lack of planning”

Impulsivity could be a predictor for compensation. Since the component Motor Impulsivity is coined as Response Inhibition Deficit, it may be assumed that more impulsive participants would be less restrained in their impulse to compensate. In Larson et al.’s study (2008), subjects’ vocal folds were anesthetized during acoustic feedback perturbations in F0 in order to inhibit somatosensory feedback from the vocal folds. Subjects compensated significantly more on anesthesia and Larson et al. concluded that the absence or unreliability of somatosensory feedback results in the enhancement of auditory feedback, hence more compensation.

Hypothesis

My assumption is that if lack of restraint of somatosensory feedback enhances compensatory behavior, then high impulsivity, also described as lack of impulse control, would too enhance compensation. And vice versa, low impulsivity may be less likely to inhibit somatosensory feedback and thus, less likely to enhance compensation. As an industry standard, the Barrat Impulsivity Scale 11 is used in this study (Patton et al., 1995).

Power

Keltner et al. (2003) “define power as an individual’s relative capacity to modify others’ states by providing or withholding resources or administering punishments”. If people with less power, by definition, have less control over their and others’ outcomes, and their fates are more dependent on situational circumstances (Magee et al., 2005), then they would “typically seek the most diagnostic information” and pay more attention to situational cues and context (Fiske & Depret, 1996).

Furthermore, Galinsky et al. (2006) propose that “power might inhibit one’s ability to pay attention to and comprehend others’ emotional states”. In a series of experiments, they demonstrate that subjects primed with power exhibit reduced empathy and ability to take other people’s perspectives.

Evidence that high-power (primed with power) subjects exhibit less behavioral self-awareness than those without power comes from Ward & Keltner’s “cookie experiment” (1998). High-

powered subjects demonstrated their reduced behavioral self-awareness by “chewing (cookies) with their mouths open and spilling more crumbs on their faces and on the table” (Magee et al., 2005). Finally, Galinsky et al. (2008) show that “power psychologically protects people from influence”. In a string of experiments, they found that high-power subjects tend to be less influenced by situational circumstances. The researchers claim that high-power subjects rely more on their intrapsychic cognitive processes rather than on situational and interpersonal ones, and thus, are generally more immune to manipulation.

In summary, from the research above may be assumed that high-power individuals

- are less sensitive to situational cues and in general, pay less attention to external situational context
- monitor their behavior less, and are less self-aware
- are more rigid and consistent with their dispositions, relying more on intrapsychic processes than on situational and interpersonal ones
- are more immune to influence from situational pressures

Hypothesis

Based on the research summarized above, for the purposes of the current study, it may be assumed that subjects who score high on power would pay less attention to their auditory feedback and monitor their speech production less. In the face of reduced reliance on auditory feedback, and increased rigidity of speech production, high-power subjects would compensate less when faced with an auditory feedback manipulation. And vice versa, low-power individuals would compensate more. The established procedure to investigate the psychology of power is to prime participants with power. However, the exploratory nature of the current study aimed at avoiding any priming in order to be able to test for multiple variables. To obtain a measure of power, a 28-item scale used to measure empowerment among users of mental health services was chosen (Rogers et al., 1997) (attached in appendix). The empowerment scale consists of five subcomponents: power/powerlessness, optimism and control over the future, self-esteem, community activism and autonomy, and righteous anger.

Big Five Personality Test

The Big Five Personality test (Saucier, 1994) is among the most popular tests in the Psychology field. It broadly categorizes human personality into five traits: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, Intellect or Openness.

Hypothesis

This test significantly widens the scope of the current study, but may be a useful starting point in the search for personality factors possibly influencing compensation for altered auditory feedback.

Methods

This study was approved by UC Berkeley’s Committee for Protection of Human Subjects (CPHS Protocol Number 2010-08-2016). CPHS’s standards were followed in every step of the experiment.

Subjects

46 male (42 white and 4 Asian) college students between the ages of 18 and 25 were selected for this study. Automatic, real-time extraction of formants in female speech is error-prone for the current version of the speech analysis software used, thus valid data was only possible with male participants. All subjects were native speakers of English, raised in California. Five were bilingual and 11 were fluent in a second language. None of them reported having any hearing, speech, or language disorders. They were compensated \$10 for up to an hour of total experiment time.

Materials and Procedure

This experiment was divided into two parts: Speech Experiment and Questionnaires:

1. Speech Experiment

The speech experiment part of this study utilizes the same technology used in Katseff & Houde's experiment (2008). The procedure was very similar, but the parameters were slightly different:

Participants were seated in a soundproof booth and wore an AKG HSC-271 Professional headset. Their speech was routed from the headset microphone through a Delta 44 sound card. Speech was analyzed and re-synthesized in real time. Re-synthesized speech was played through the headset's earphones in place of normal auditory feedback

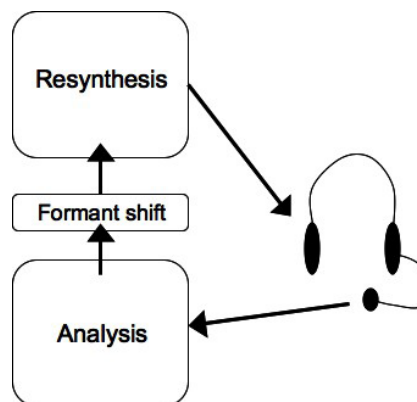


Figure 1: Schematic of Experimental Setup. Subjects speak into the microphone portion of a headset. Their speech is analyzed, then re-synthesized (and shifted, if necessary) and fed back into the headset's earphones.

(Katseff & Houde, 2008)

1.1. Vowel Inventory

During the first "Vowel Inventory" part of the speech experiment, naïve subjects were recorded while reading words off of a computer screen. The following words were displayed one by one in a random order for a total of 165 trials, with equal probability of selection: /hɪd/, /hɪd/, /hɛd/, /hæd/, /ɑd/, /ɔd/, /hɒ^od/, /hʊd/, /hud/, /bud/, /pug/, /rud/, /dud/ (heed, hid, head, had, odd, awed, hode, hood, who'd, bood, poog, rude, dude). Words were displayed on the screen for ~2500ms each and during that time frame, the subject had to read the word and be recorded. The experiment was self-paced. Words were appearing in sets of 15 trials and subjects could take breaks in between sets for as long as they wished. No formants were shifted during this part of

the experiment. Among all 165 trials, the number of /u/ tokens from both ‘bood’ and ‘poog’ combined was on average 26.

1.2. Formant Shift

The second “Formant Shift” part of the speech experiment consisted of 210 trials of only two randomly generated words: /bud/ and /pug/. Preceding labial plosives were chosen as an /u/ environment that normally results in relatively non-fronted production, as opposed to fronted coronals that elicit significantly fronted /u/. The environment of /b-p/ would arguably leave room for compensatory /u/-fronting, since the average distance from /b-pu/ to /du/ could be as big as slightly above 300Hz (Hagiwara, 1995). As mentioned above, compensation may be unrestricted as long as it is within one’s baseline vowel region (Katseff & Houde, 2008). Thus, /b-pu/’s hypothetical 100% compensation of 300Hz would easily extend to as much as an average value of /u/ in a coronal environment.

The words /bud/ and /pug/ were displaced in the same format like in the first part of the experiment, but this time, the second “formant was altered in real time using a feedback alteration system” (Katseff & Houde, 2008). The system, designed by Houde (2002), “takes in small time-windows of sound and quickly re-synthesizes them using a synthesis, which can replicate a speech signal with very good accuracy from a small amount of data” (Katseff & Houde, 2008). From exit interviews at the end of the entire study was confirmed that the altered feedback was played back undetectably fast (12ms). Nobody noticed that their feedback was altered.

The “Formant Shift” process consisted of the following 4 consecutive phases:

Phase	# of Trials	F2 Shift
1. Baseline	30	0Hz
2. F2 Shift	60	From 0Hz to -300Hz
3. Maximum Shift Plateau	100	-300Hz
4. Normal Feedback	20	0Hz

Table 1: There was no formant alteration throughout the first 30 Trials. For the next 60 trials, F2 was gradually reduced by -5Hz per trial, so that with each consecutive production, the talkers were hearing their /u/ 5Hz lower than the previous one, until it reached -300Hz. Then, for 100 trials, their feedback was held at a maximum shift plateau of -300Hz. Finally, normal feedback was restored for the last 20 trials.

The total duration of the entire “Speech Experiment” was approximately 20 minutes.

2. Questionnaires

After the “Speech Experiment”, subjects were invited in a neighboring room in the Phonology lab where they were assigned to fill in pencil-and-paper questionnaires (one is attached in the appendix). They were given the questionnaires one by one in the following order:

1. Attitude/Self-identification with California (attached in the appendix) (Svetlin Dimov, 2010):
A 20-item self-report questionnaire devised following guidelines on formatting of paper-based survey questionnaires (Fanning, 2005). The questionnaire was designed to quantify subjects’ self-identification and attitude towards their native state of California. Scoring 0% indicates total lack of self-identification and negative attitude towards California. In contrast, scoring 100% means that subjects absolutely consider themselves to be

Californian and like various aspects of being Californian. The test format represents a 7-level Likert scale questionnaire (from strongly disagree to strongly agree) where subjects must indicate their level of agreement to statements like “I consider myself to be a Californian” or “There is nothing exceptional about being from California”.

2. **Autism-Spectrum Quotient (AQ)** (Baron-Cohen et al., 2001)
A 50-item self-report questionnaire designed to place people on a continuum from least autistic to maximum autistic. The test format is a 4-level Likert scale (from strongly disagree to strongly agree) where subjects express their agreement or disagreement to statements like “I prefer to do things with others rather than on my own” or “I usually concentrate more on the whole picture, rather than the small details”.
3. **Self-Monitoring** (Snyder, 1974)
A 25-item self-administrative questionnaire designed to measure to what degree people pay attention to “the expression and self-presentation of others and use these cues as guidelines for monitoring and managing their own self-presentation and expressive behavior” (Snyder, 1974). Subjects indicate whether statements like “When I am uncertain how to act in a social situation, I look to the behavior of others for cues” or “I have trouble changing my behavior to suit different people and different situations” are true or false for them.
4. **Impulsivity** (Patton et al., 1995)
A 30-item self-report questionnaire divided into 3 subcomponents (attentional, nonplanning, and motor impulsivity) that capture and quantify the “multi-factorial nature of the construct” (Patton et al., 1995) (see above for a definition). This test utilizes a 4-level Likert scale (from rarely/never to almost always/always) that allows subjects to express how frequently they think or act as statements like “I am self controlled” or “I say things without thinking” describe.
5. **Empowerment Scale** (Rogers et al., 1997)
A 28-item self-report questionnaire divided into 5 subcomponents (Self-esteem, Power/Powerlessness, Community Activism and Autonomy, Optimism and Control over the Future, Righteous Anger) that taken as a whole make up a construct of empowerment. Originally designed for users of mental health services, the questionnaire provides an opportunity to measure empowerment globally or in its sub-components. This test uses a 4-level Likert scale (from strongly disagree to strongly agree). Subjects agree or disagree to statements like “I feel powerless most of the time” or “I can pretty much determine what will happen in my life”.
6. **Big Five Mini-Markers** (Saucier, 1994)
A self-report test utilizing a 9-point Likert scale (from 1-extremely inaccurate to 9-extremely accurate) where subjects are given 40 adjectives to describe themselves. These adjectives categorize people into five basic traits: Extraversion, Agreeableness, Conscientiousness, Emotional Stability, Intellect or Openness. Within each category, score can exhibit great variability.

7. A questionnaire collecting information about subjects':
Foreign Language Knowledge, California Dialect, Residential history, Age, Race,
Education, Parents' Professions.

On average, subjects managed to fill in the questionnaires within 30 minutes. The whole study lasted approximately 50 minutes. At the end, subjects were asked whether they felt their feedback delayed and how much it sounded like their voice. None of them reported to have perceived a delay. Even though they experienced some noise and a slight distortion in the feedback signal, all subjects reported that the voice they heard was their voice and none of them noticed that their feedback was altered. Finally, subjects were fully debriefed and allowed to withdraw their data from the analysis.

Data analysis

Audio recordings and filled questionnaires from all 46 subjects were used.

- Vowel formants were measured using Esps/xwaves, and verified using PRAAT (Boersma & Weenink, 2008).
- /u/ baseline = mean F2 value of first 30 trials of the "Formant Shift" part that were not altered. [This /u/ baseline was compared with the mean F2 value of /u/ (bood/poog) production of the "Vowel Inventory" part]
- F2 compensation = [mean F2 value of /u/ production during the "Maximum Shift Plateau" phase]-[/u/ baseline (first 30 trials)]
- Outliers in all production phases that were caused by inaccurate formant extraction software were manually corrected where possible by looking at spectrograms with PRAAT. Where not possible, they outliers were discarded. Outliers were less than 10% of all production.
- Questionnaires were scored using guidelines provided by the questionnaire authors. The questionnaire measuring attitude/self-identification with California was scored by converting the 7-level scale to a 7-point scale where "strongly disagree" = 1, and "strongly agree" = 7. Then, all values were summed (after reversing the reverse questions) and divided by the maximum total score possible. With the exception of the Autism-Spectrum Quotient (AQ), all scores have values from 0 to 1 (0% to 100%). The AQ is scored on a scale from 0 to 50.
- A total of 28 variables were considered as possible predictors for F2 compensation
- Forward stepwise regressions using the Akaike Information Criterion (AIC) were conducted to determine the best predictors for compensation

Results

Mean baseline F2 of /u/ in a labial (/bud/ and /pug/) environment was 1315Hz ('BU'). Mean baseline F2 of /u/ in a coronal (/dud/) environment was 1618Hz ('DU').

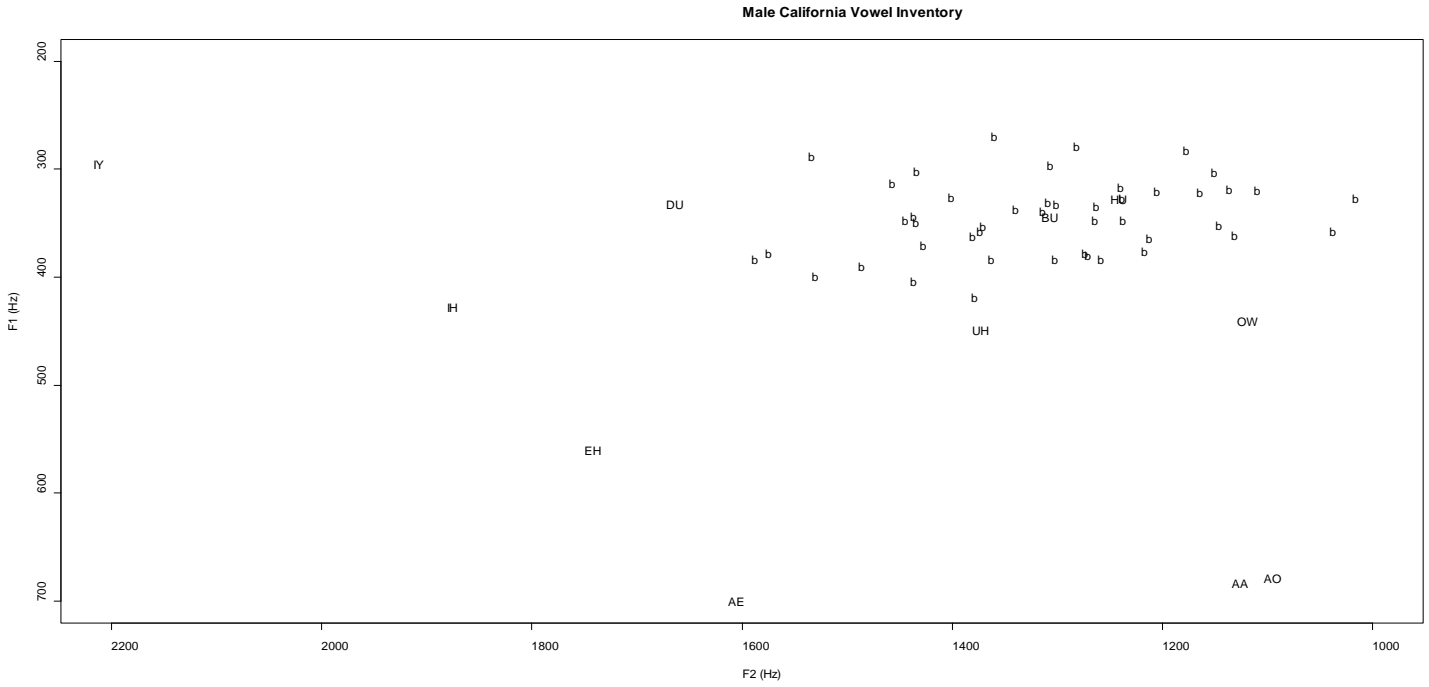


Figure 2: Mean baseline /bu-/pu/ (marked /b/) of **each** of the 46 subjects. Mean baseline /BU/, /DU/, and /HU/ of **all** subjects combined. Mean baseline vowels off **all** subjects combined using the Buckeye corpus labels.

The majority of the subjects compensated (increased the F2 of the /u/ vowel production in response to auditory feedback of /u/ vowels with decreased F2):

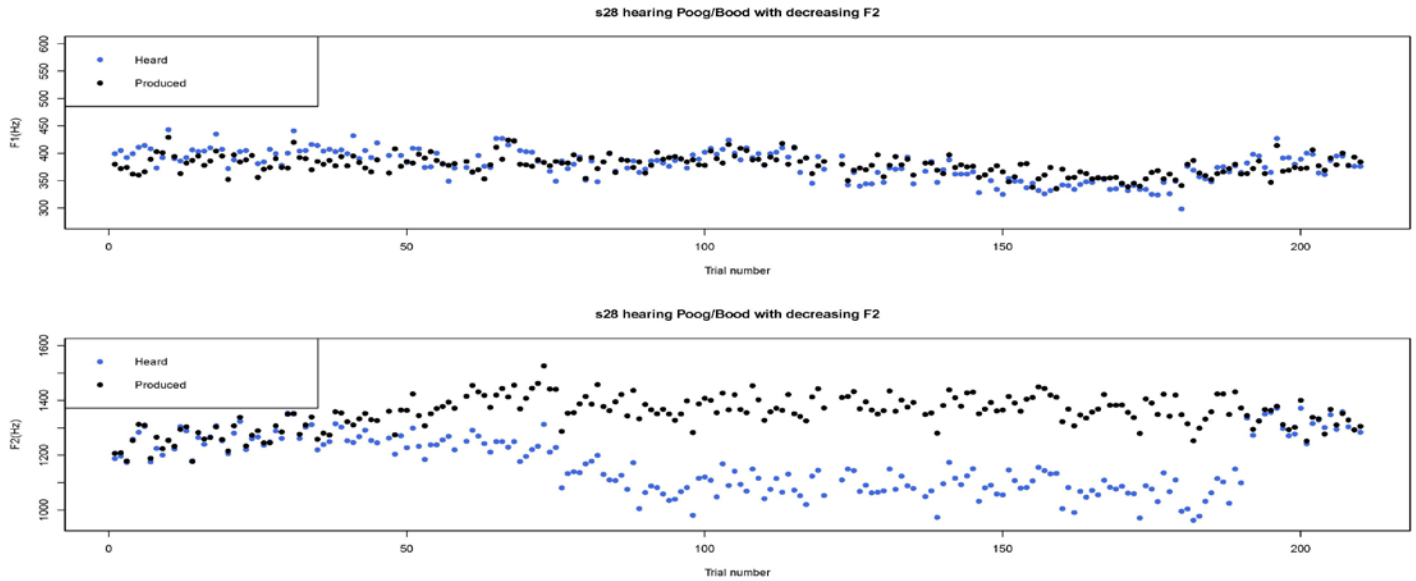


Figure 3: The upper plot shows no compensation in the F1 dimension. The lower plot displays gradual F2 shift of auditory feedback and resultant compensation in production.

Subjects compensated to various degrees:

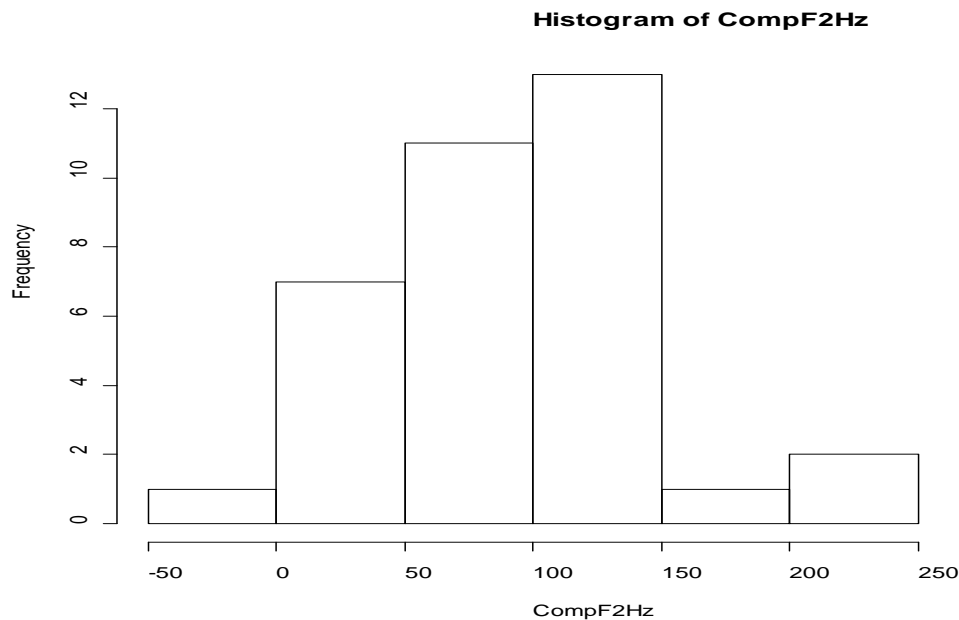


Figure 4: Degree of compensation. On the y-axis is displayed the number of subjects that compensated (increased their F2) to various degrees (compensation in Hz is presented on the x-axis)

Two forward stepwise multiple regressions using the Akaike Information Criterion (AIC) were conducted in order to determine the best predictors for compensation: 1) including data from all 46 subjects; 2) Including data only from 35 monolingual² subjects.

- 1) From the first regression using data from all 46 subjects emerged four reliable predictors accounting for 53% of the variance (adjusted $R^2 = .529$): “Optimism & Control over the Future” [$t(33) = -3.7, p < .001$], “Power” [$t(33) = -2.5, p < .05$], “F2 of baseline /u/” [$t(33) = -3.3, p < .01$], and “Second Language Fluency in Telugu” [$t(33) = 2.3, p < .05$].

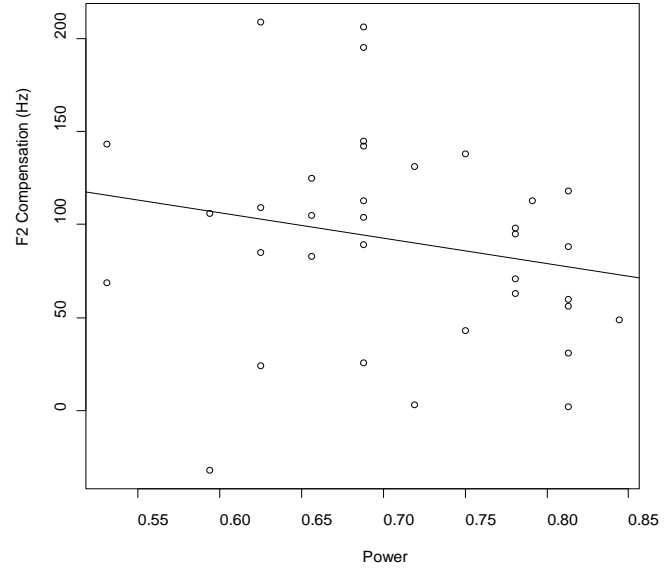
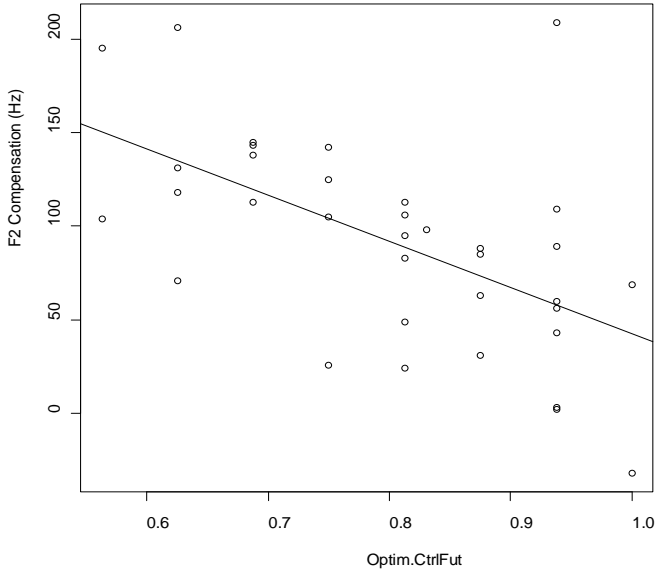
Since “Second Language Fluency in Telugu” emerged as a reliable predictor for F2 compensation and there was only one subject whose second language was Telugu, a second regression with data only from 35 monolingual speakers was conducted.

- 2) From the second forward stepwise regression (35 monolingual subjects) using the Akaike Information Criterion (AIC) emerged 3 reliable predictors for F2 compensation accounting for 48% of the variance (adjusted $R^2 = .479$):

² Of the 11 subjects who were excluded from the data analysis 5 were bilingual, and 6 were monolingual English speakers who were fluent in a second language.

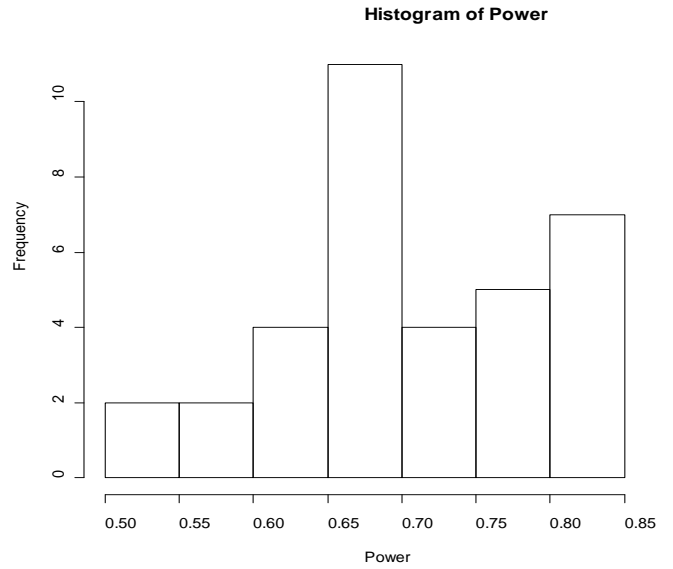
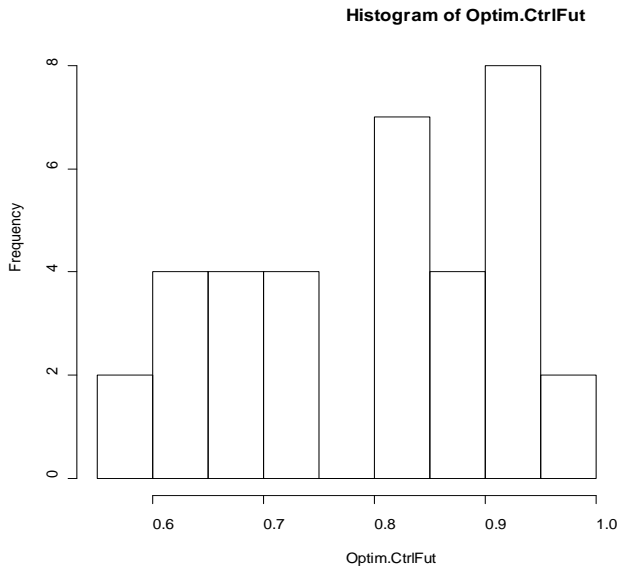
“Optimism & Control over the Future” was a reliable predictor for F2 compensation [$t(31) = -4.3, p < .001$]

“Power” was a reliable predictor for F2 compensation [$t(31) = -2.4, p < .05$]

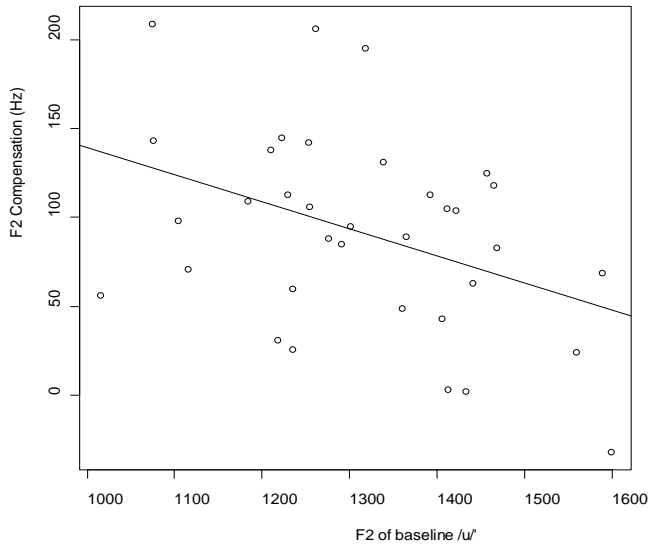


Distribution of self-reported “Optimism and Control over the Future”

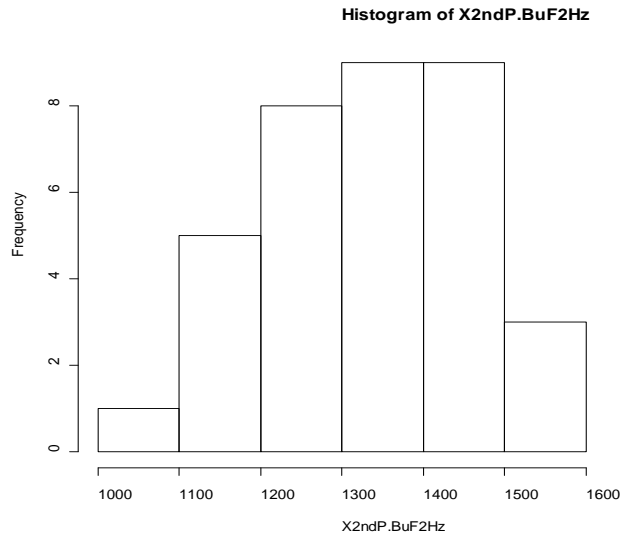
Distribution of self-reported “Power”



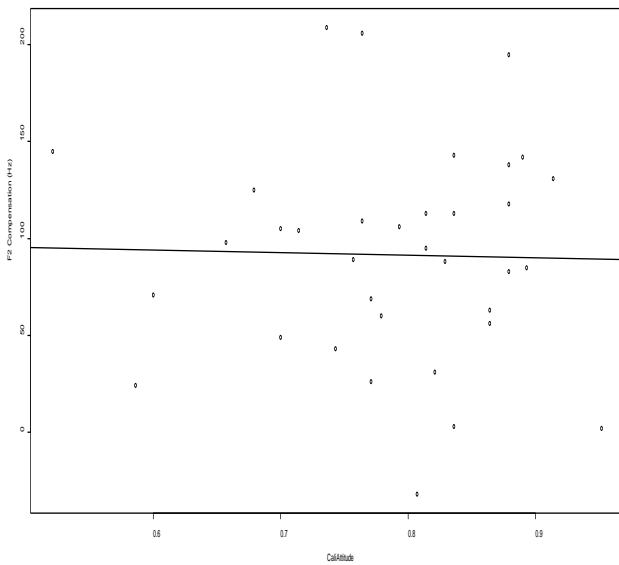
“F2 of baseline /u/” was a reliable predictor for F2 compensation [$t(31) = -3.1, p < .01$]



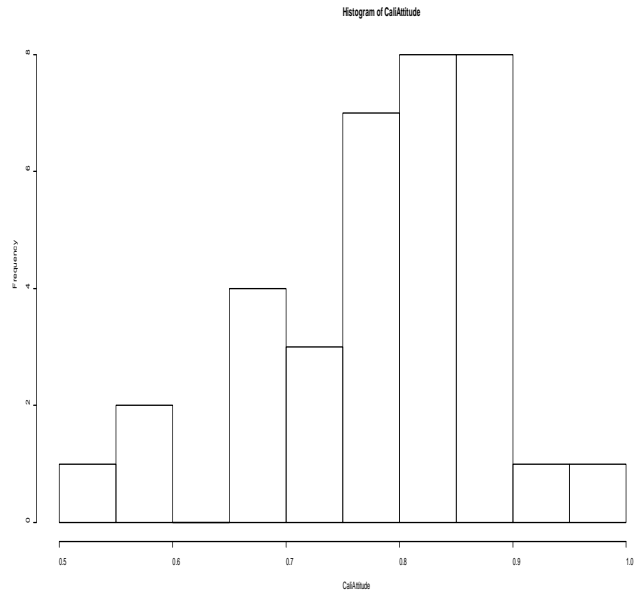
Distribution of baseline /u/ region in preceding labial environment (/bu/-/pu/)



“Attitude and Self-identification with California” was not a predictor for compensation



Distribution of self-reported “Attitude and Self-identification with California”



Discussion

From the vowel space graph of the current subject pool is evident that, consistently with previous research (Hagiwara, 1995; Clopper, 2004; 2005; Labov et al., 2006), California English exhibits a fronted /u/ vowel region. Some external validity for this subject pool's representation of a typical California /u/ is lent especially by Hagiwara's study (1995) that 15 years ago reported very similar mean values for California male /u/. Hagiwara's observed mean /u/ values in a preceding coronal (/tu/) and labial (/bu/) environment were respectively 1679Hz and 1341Hz, and this study's averages were respectively 1618Hz and 1315Hz.

Furthermore, the patterns of compensation demonstrated by the majority of the subjects in this study resemble those documented in previous studies; most subjects significantly changed their production towards the opposite direction of the manipulation. Additionally, this study observed similar variability in the amount of compensation. Some subjects compensated almost completely, most about 30% of the manipulation amount, and some even failed to compensate at all and merely wandered around their baseline.

The broad hypothesis, that the unexplained variability in compensatory behavior may be due to independent variables related to social or personality factors that independently affect compensation for altered auditory feedback, was confirmed for this subject pool. Two subcomponents of empowerment (Optimism & Control over the Future and Power/Powerlessness) were significantly negatively correlated with amount of compensation. The statistical analysis demonstrated that the less powerful subjects felt, and the less they were optimistic about their future and felt that they have control over it, the more they reacted to the manipulation by demonstrating a compensatory behavior. And vice versa, the more empowered subjects felt, the less they compensated. This finding may be interpreted to be consistent with the literature on power quoted above (Fiske & Depret, 1996; Ward & Keltner, 1998; Magee et al., 2005; Galinsky et al., 2006; 2008). The linguistic behavior (production during altered auditory feedback) of the low-power subjects in this experiment does not appear to differ from the general behavior of people with reduced sense of power. It is possible that, just like low-power participants in other studies, these subjects were more reliant on situational cues, paid more attention to their auditory feedback, monitored their speech production more, and their linguistic behavior was in general more susceptible to influence. As a consequence, they arguably upweighted their auditory feedback and compensated more for the manipulation.

California identity was not a predictor for compensation. Assuming that the devised questionnaire was able to reflect subjects' attitudes and self-identification with California, it seems possible that: 1) the participants did not associate a more backed /u/ with another region of California; 2) if they did recognize that their /u/ production sounded unlike non-Californian, they did not consider it threatening because they had positive attitudes towards regions, people, culture, and everything else they associate with a more backed /u/; 3) for this subject pool, fronted /u/ was not a marker of regional identity. Ideally, other experimental designs (e.g. priming one group of participants with pro-California sentiment before the feedback alteration and then observing differences in compensation with the control group) would provide a better measure for the significance of Californian dialect as a marker of regional identity.

The other significant negative correlation that emerged from the statistical analysis was that the less fronted (lower F2) subjects' baseline /u/ was, the more they compensated by increasing their F2. One possible hypothesis is that subjects with lower baseline /u/ regions (~ 1000-1100Hz) heard themselves pronounce their /u/ unusually low, at ~ 700-800Hz and felt especially

motivated to avoid this unnaturally low sounding /u/. This divergence is different from the one hypothesized to occur due to non-California sounding /u/, in that, the 700-800Hz /u/ is approaching the boundaries of natural human production, whereas the average /u/ of most American English varieties (with the exception of Southern English) is situated around 900-1100Hz.

In conclusion, this paper argued for an effect of social and personality variables on compensation for altered auditory feedback, and provided evidence that a personality variable, empowerment, independently affects amount of compensation. The fact that a construct derived entirely from social interactions can influence speech so significantly lends support for the inclusion of a sociophonetic approach towards the research on what are considered to be purely phonetic phenomena.

Finally, the findings of this study warrant a more in-depth investigation on the effect of empowerment on speech processing that ought to include all segments of the population and utilize a wide variety of experimental procedures. If empowerment proves to be consistently affecting all aspects of speech production, then it might be a good candidate to be included in the list of possible motivators of sound change. If traditionally powerless segments of the society (e.g. people of lower social class, women, etc.) are more likely to be systematically inclined to alter their speech when exposed to a novel phonetic convention, then they could potentially be presumed to be facilitating diffusion of sound change.

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Appendices

Appendix 1: "Attitude/Self-identification with California" questionnaire.

Appendix 2: "Empowerment" questionnaire.

DIRECTIONS: People differ in the ways they act and think in different situations. How much do you agree or disagree with the statements below? Read each statement and put an X in the appropriate column on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.							
	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree
1. I consider myself to be a Californian.							
2. My family considers me to be a Californian.							
3. There is nothing special about being a Californian.							
4. My friends consider me to be a Californian.							
5. Sometimes I am ashamed of being a Californian.							
6. I love and am devoted to the state of California.							
7. I hope to move out of California within the next 5 years.							
8. Most California residents enjoy living in California.							
9. There is nothing exceptional about being from California.							
10. I don't think of myself as a Californian.							
11. My family doesn't regard me as a Californian.							
12. I find it easy to live in California.							
13. My friends don't regard me as a Californian.							
14. I am proud of being a Californian most of the time.							
15. I dislike the state of California.							
16. Being a Californian is cool.							
17. Most California residents don't like living in California.							
18. I would rather live in California than anywhere else.							
19. California is a unique place to be from.							
20. Living in California is hard.							
	Strongly Disagree	Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Agree	Strongly Agree

Directions: People differ in the ways they act and think in different situations. How much do you agree or disagree with the statements below? Read each statement and put an X in the appropriate column on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree
1. I can pretty much determine what will happen in my life.				
2. People are limited only by what they think is possible.				
3. People have more power if they join together as a group.				
4. Getting angry about something never helps.				
5. I have a positive attitude toward myself.				
6. I am usually confident about the decisions I make.				
7. People have no right to get angry just because they don't like something.				
8. Most of the misfortunes in my life were due to bad luck.				
9. I see myself as a capable person.				
10. Making waves never gets you anywhere.				
11. People working together can have an effect on their community.				
12. I am often able to overcome barriers.				
13. I am generally optimistic about the future.				
14. When I make plans, I am almost certain to make them work.				
15. Getting angry about something is often the first step toward changing it.				
16. Usually I feel alone.				
17. Experts are in the best position to decide what people should do or learn.				
18. I am able to do things as well as most other people.				
19. I generally accomplish what I set out to do.				
20. People should try to live their lives the way they want to.				
21. You can't fight city hall (authority).				
22. I feel powerless most of the time.				
23. When I 'm unsure about something, I usually go along with the rest of the group.				
24. I feel I am a person of worth, at least on an equal basis with others.				
25. People have a right to make their own decisions, even if they are bad ones.				
26. I feel I have a number of good qualities.				
27. Very often a problem can be solved by taking action.				
28. Working with others in my community can help to change things for the better.				
	Strongly Disagree	Slightly Disagree	Slightly Agree	Strongly Agree