The Effect of Accent on Acoustic Cues to Stop Voicing and Place of Articulation in Radio News Speech

Heejin Kim[1], Jennifer Cole[1], Hansook Choi[1] & Mark Hasegawa-Johnson[2]

Department of Linguistics[1]; Department of Electrical and Computer Engineering[2]
University of Illinois at Urbana-Champaign
{hkim17;j-cole5;hchoi5;jhasegaw}@uiuc.edu

Abstract

In previous research evidence for the effects of stress and accent on phonetic variation is based on laboratory speech. In the present paper, we report on a study of the effects of accent on the acoustic cues for stop voicing and place of articulation in the speech of four announcers from the Boston University Radio News corpus. The results show that there are significant effects of accent on VOT, F_0 and Closure Duration for voicing contrasts and significant effects on VOT and Closure Duration for place contrasts. In addition, comparison of the patterns of accentual effects reveals that the effect on voicing cues has a pattern of paradigmatic strengthening and combined strengthening, resulting in enhancement of voicing contrasts while syntagmatic strengthening appears to be the main effect on acoustic cues for place of articulation.

1. Introduction

Earlier studies on the effect of stress and accent provide evidence of stress/accent-induced strengthening in both articulatory and acoustic features of speech. The major finding in articulatory studies is that syllables with lexical stress or phrasal accent are produced with greater speech gestures such as greater spatial displacement, longer duration and greater peak velocity [1, 2, 3, 5, 6, 7]. Acoustic studies on accent effects report comparable results. Longer duration of vowels and consonants are found under lexical stress [4, 11] and also under phrasal accent [7, 10]. Increased VOT is also reported as acoustic evidence for the accentual strengthening [9]. The increased spectral rate of change in the transition between vowel and adjacent liquids and glides provides another evidence of the effect of accent on spectral features [12].

Most of these previous studies are based on laboratory read speech, which consists of highly controlled scripts prepared by the experimenter. It is yet to be discovered how stress and accent influence phonetic variation in non-laboratory speech where phrasing and the location of prosodic prominence are selected by the speaker and not controlled by experimenter.

In this study we examine the speech of four announcers from the Boston University Radio News corpus to investigate the effects of phrasal accent on acoustic cues. Our main interest is on the acoustic cues that encode Voicing and Place of Articulation (POA) of stop consonants. Based on measurements from four acoustic features - VOT, F_0, Closure Duration and Burst Amplitude, we address what type of strengthening is induced by phrasal accent in the cues to Voicing and POA.

2. Method

2.1. Material

The target consonants were taken from the lab-news portion of Boston University Radio News corpus. In this portion of the corpus, news stories that had been recorded during broadcast in the WBUR radio studio were read by professional announcers in a laboratory at Boston University. They were asked to read the stories in their radio style. This study examines all the lab news data for four speakers F3A, F2B, M1B and M2B out of six speakers. The database we analyzed includes hand-labeled prosodic markings such as pitch accents and phrasal boundaries, following the ToBI labeling standard.

2.2. Acoustic analysis

Stop consonants /p b t d k g/ were all extracted from medial positions of the Intonational Phrase (IP) and word-initial, pre-vocalic positions (#CV). Stops in word-initial consonant clusters are excluded in this study. All the tokens are categorized as Accented or Unaccented, depending on the presence or absence of pitch accent on the syllable where consonants are from. Table 1 shows the distribution of the target consonants according to Accent conditions for each speaker.

Table 1. *Distribution of stop tokens for each speaker according to Accent condition. All stop tokens occur IP-medially, word-initially and are followed by a vowel*

Speaker	Accent	**p**	**b**	**t**	**d**	**k**	**g**
F3A	U	19	40	59	21	32	14
	A	17	24	17	9	24	5
F2B	U	23	39	44	21	37	13
	A	7	21	17	6	17	3
M1B	U	14	51	67	29	31	14
	A	18	21	18	10	28	7
M2B	U	17	32	34	22	26	10
	A	16	26	17	14	21	8

The target consonants were all manually segmented and labeled for acoustic measurements that are listed below, based on spectrogram, waveform and listening.

- VOT: The measurements were taken from the onset of the release burst to the zero crossing nearest to the onset of the second formant of the following vowel.
- F_0: To measure F_0 at the onset of voicing following stop release, it was manually calculated from the duration of the first three glottal pulses.

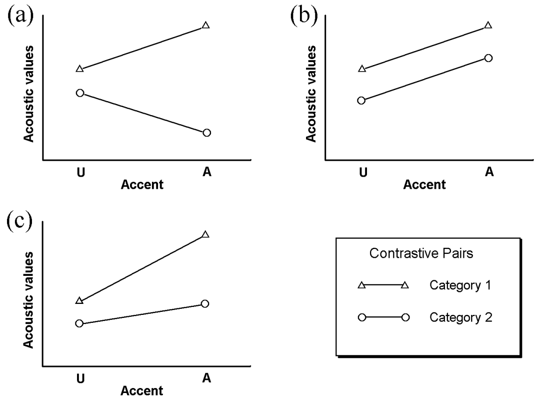

Figure 1: *Schematic diagram of patterns of strengthening: (a) Paradigmatic, (b) Syntagmatic, (c) Combined.*

- Closure Duration (CD): In the context of a preceding vowel or liquid, the beginning point of CD was marked at the point where the second and higher formants end. If the preceding sound is a stop, the beginning point was marked right after the stop release. If there was no stop release, no CD measurement was performed. In the context of a preceding fricative, the beginning point was marked at the end of frication noise.
- Burst Amplitude (BA): BA was measured on the basis of RMS intensity measured in a 10 ms window, with the first peak of the burst as the beginning point.

2.3. Hypothesis

Two different patterns of strengthening are possible as the effect of phrasal accent. One is paradigmatic strengthening whereby the distinctiveness of phonologically contrastive sounds is enhanced. The other is syntagmatic strengthening which accompanies enhancement of contrast between adjacent sounds but no contrast enhancement between phonologically contrastive sounds.

Under the hypothesis of paradigmatic strengthening, we expect phrasal accent to enhance the distinctiveness between voicing categories or between different POA categories. Thus, along the given acoustic measurement, we expect contrastive categories to show the opposite direction of change under Accent as shown in the schematic diagrams in Figure 1a. For example, in the case of voicing cues, we expect increased VOT, F_0, CD or BA for a voicing category with a higher value, but for the opposing category we expect decreased values. Under the hypothesis of syntagmatic strengthening, we expect to find a uniform increase of acoustic values in contrastive categories, as shown in Figure 1b. Figure 1c shows the case of combined strengthening whereby the direction of change is the same for both categories, but the category with a lower value is increased by a lower amount compared to the category with a higher value. This pattern of strengthening results in more separation of two categories under Accent, as in the case of paradigmatic strengthening.

To test these hypotheses, 2-way ANOVA is performed to examine if an interaction between Accent and Voicing or POA is significant. Significant interaction means that the difference between the Voicing or POA categories is different for each Accent condition. This pattern corresponds to paradigmatic strengthening and the combined strengthening as in Fig 1a and Fig 1c. On the other hand, the lack of interaction means that the difference between the Voicing or POA categories is uniform across different Accent conditions, which is a pattern of syntagmatic strengthening as in Fig 1b.

3. Results

We first report the effect of Voicing and POA on the acoustic measures of VOT, F_0, CD and BA to show that these cues indeed play a role in marking Voicing and POA contrasts. Results for the effect of Accent on Voicing and POA cues are presented in the next section.

3.1. Acoustic cues for Voicing and POA contrasts

According to 2-way ANOVA with the independent factors of Voicing and POA, a significant effect of Voicing is found on VOT at $p< .001$ and on F_0 at $p< .05$ for all speakers. Two speakers (F3A and M2B) show a significant effect on CD at $p< .05$ and two speakers (F2B and M2B) have a significant effect on BA at $p< .05$. Bar graphs for acoustic measures for voicing cues are shown in Figures 2. It is clearly shown that VOT and F_0 is greater for voiceless stops than for voiced for all speakers. CD is found to be higher for voiced stops and BA is higher for voiced stop for speakers F2B and M2B. We note that the difference between voicing categories are best manifested by VOT, suggesting that VOT is the most effective cue for Voicing.

Significant effects of POA are found for all speakers on VOT at $p< .05$ and on CD and BA at $p< .01$. No significant effect is found for F_0. Bar graphs for VOT, CD and BA with respect to different POAs are shown in Figures 3. The POA grouping for each acoustic measure is quite different across speakers. The main trend is Labial < Alveolar < Velar for VOT, Alveolar = Velar < Labial for CD and Labial < Alveolar for BA.

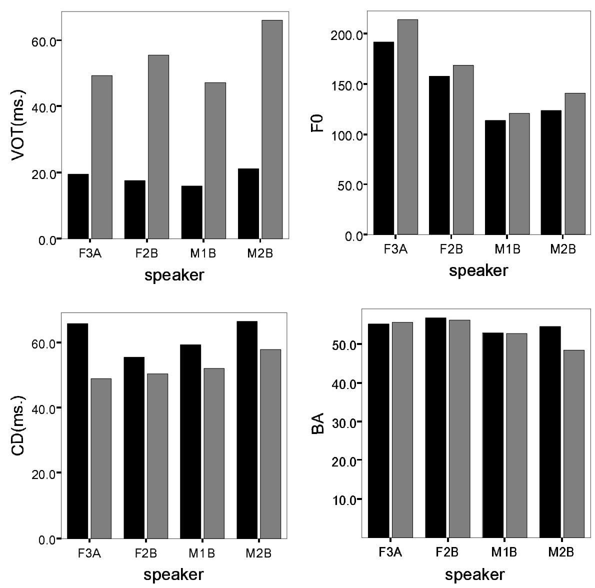

Figure 2: *Bar graph of VOT, F_0, CD and BA for voiced (black) and voiceless stops (gray)*

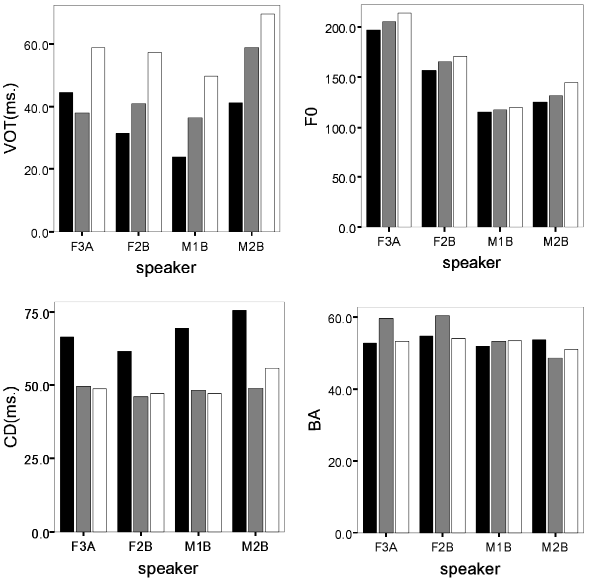

Figure 3: *Bar graph of VOT, F_0, CD and BA for Labial (black), alveola(gray), velar(white)*

3.2. Effect of Accent

3.2.1. Effect of Accent on Voicing cues

According to 2-way ANOVA with the independent factors of Accent and Voicing, a significant effect of Accent is found on VOT and CD for all speakers at $p< .01$. Three speakers (F3A, F2B, M1B) show a significant effect of Accent on F_0 at $p< .05$. And only one speaker (M1B) shows a significant effect on BA at $p< .05$.

There is a significant effect of interaction between Accent and Voicing on VOT for all speakers at $p< .05$. Three speakers (F3A, F2B, M1B) show a significant interaction on F_0 at $p< .05$ and two speakers (M1B, M2B) show a significant interaction on CD at $p< .05$.

In order to see the pattern of strengthening under Accent for VOT, F_0 and CD which show significant effect of Accent in most speakers, dot graphs are plotted pooling data across POAs in Figure 4-6. It is clearly shown that VOT is increased under Accent for both voiced and voiceless in speakers F3A and M2B, with greater increase for voiceless stops than voiced stops. In speakers F2B and M1B, VOT is increased under Accent for voiceless but it is decreased for voiced. F_0 is found to be increased under Accent for both voiced and voiceless, with greater increase for voiceless stops, in three speakers. CD is also found to be increased under Accent for both voiced and voiceless, but it exhibits greater increase for voiced stops, except speaker M1B: M1B shows an unusual pattern where a category with a lower value (voiceless stop) increases more than a category with a higher value (voiced stop), resulting in weakening of contrast under Accent.

3.2.2. Effect of Accent on POA cues

2-way ANOVA was performed for VOT, CD and BA, but not for F_0 since in the previous section F_0 is found to be not used as a POA cue by any speaker. The results of 2-way ANOVA with the independent factors of Accent and POA reveal that there is a significant effect of Accent on VOT and CD for all speakers at $p< .01$. Only one speaker (M1B) shows a significant effect of Accent on BA at $p< .05$. In addition, it is found that there are few significant interactions between Accent and POA. Only VOT in speakers F2B and M1B is found to have significant interactions between Accent and POA at $p< .05$. In other words, regarding the effect of Accent on POA cues, the lack of interaction between Accent and POA is found in most cases. Fig 7 displays dot graphs with CD measurements.

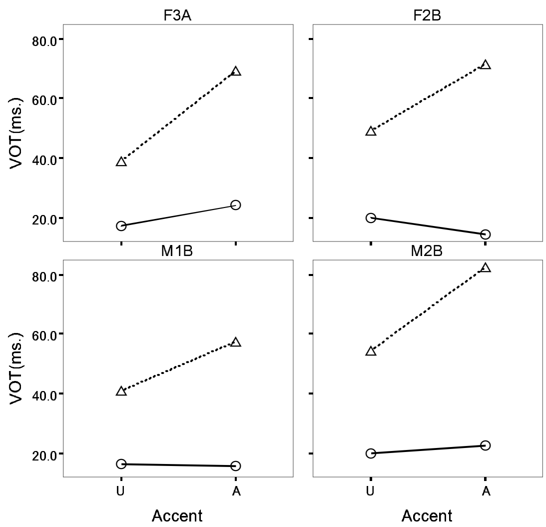

Figure 4: *Effect of Accent on VOT for voicing: U-unaccented, A – accented, ○-voiced, △-voiceless*

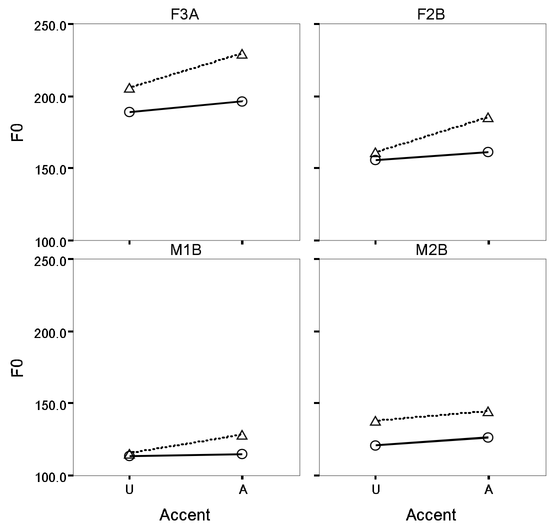

Figure 5: *Effect of Accent on F_0 for voicing: U-unaccented, A – accented, ○-voiced, △-voiceless*

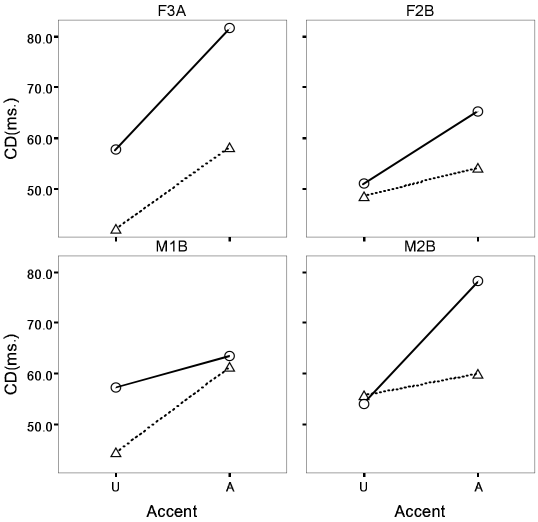

Figure 6: *Effect of Accent on CD for voicing: U-unaccented, A – accented, ○-voiced, △-voiceless*

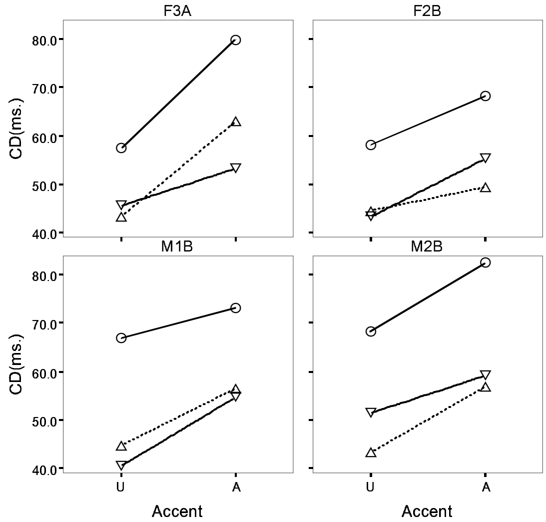

Figure 7: *Effect of Accent on CD for POA: U-unaccented, A – accented, ◯-labial, △-alveolar, ▽-velar*

4. Discussion

Our first finding in this study is that significant effects of Voicing are found on the acoustic measures of VOT, F_0, CD and BA while significant effects of POA are found on the acoustic measures of VOT, CD and BA. These findings demonstrate that speakers are indeed using these cues to mark the phonological contrasts of Voicing and POA.

As to the effect of Accent on voicing cues, we find significant effects of Accent on acoustic measures for VOT, F_0 and CD. The examination of interaction between Accent and Voicing category demonstrates that in most cases the degree of increase is bigger for the voicing category with a higher value than for the voicing category with a lower value, resulting in enhanced contrast of voicing categories under Accent. Along with this combined strengthening, in sporadic cases (VOT in F2B and M1B), Accent induces changes in opposite directions for voicing categories: decrease for voiced and increase for voiceless. This paradigmatic strengthening also results in enhanced contrast of voicing categories. These findings suggest that the major effect of Accent on voicing cue is enhancement of voicing contrast.

As to the effect of Accent on POA cues, significant effect of Accent was found on acoustic measures for VOT and CD. However, interaction between Accent and POA cues is found to be not significant in most cases. That is, unlike the effect of Accent on voicing cues, a uniform increase of acoustic values of VOT and CD is found across different POA categories – a pattern of syntagmatic strengthening, suggesting that the primary function of Accent may not be the enhancement of phonological contrasts of POAs.

5. References

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