

LINGUAL CONTACT IN SELECTED ENGLISH VOWELS AND ITS ACOUSTIC CONSEQUENCE

Ivan Yuen; Alice Lee; Fiona Gibbon

Psychology, Royal Holloway; Speech & Hearing Sciences, University College Cork; Speech & Hearing Sciences, QMU

ivan.yuen@rhul.ac.uk; a.lee@ucc.ie; fgibbon@qmu.ac.uk

ABSTRACT

This paper provides preliminary data about EPG contact for 3 different vowels in Southern British English (SBE) and Scottish English (SE) across eleven speakers. The EPG data were compared with vowel formants to test the hypothesis that the amount of EPG contact as an indicator of tongue height or anteriority will result in a corresponding change in F1 and F2. The results suggest that Percent Contact varies with the three monophthongs. F1, F2 and F2-F1 difference varies with the amount of Percent Contact.

Keywords: Electropalatography, lateral bracing, vowels, articulation-to-acoustics mapping.

1. INTRODUCTION

The classical description of vowels is based on two dimensions – height and anteriority of the tongue. In studying vowels, researchers have tended to investigate the acoustics or the configuration of the tongue. In modeling the tongue configuration, an ultrasound study [1], for example, showed that four classes of tongue shape were adequate to categorise both vowels and consonants. Three classes were used in characterizing vowels: front raising, complete groove and back raising. The articulatory study showed that vowels can be characterised in terms of anteriority (front versus back) and height (raising versus groove).

The technique of electropalatography (EPG) is able to provide some indication of tongue height and anteriority – tongue palate contact occurs in most speakers for the high front and back vowels, although it is less useful for investigating low vowels because there is minimal contact during their production.

According to [2], an acoustic tube that is closed at the glottis/posterior end and open at the lips will tend to result in a lower F1 when there is a narrowing of the cross-sectional area in the

anterior part of the tube or a widening of the cross-sectional area in the posterior end of the tube. When the tongue body is raised to narrow the anterior part of the oral tract, the cross-sectional area anterior to the constriction between the tongue dorsum and the palate decreases and thereby F1 decreases. As for the front-back dimension, [2] showed that forward movement of the tongue body resulted in a higher F2.

There have been few studies that have related acoustic and EPG information, so it is uncertain whether amount of lingual contact is correlated with the acoustic properties of vowels. Such evidence would be useful in providing normative EPG data for these vowels for use with individuals with speech disorders.

2. METHOD

The experiment aimed to identify the amount of EPG contact during the production of 3 vowels in English and to test whether the differences in amount of lingual contact had any acoustic consequences in Formant 1 (F1), Formant 2 (F2) and corresponding F2-F1 difference.

2.1. Instrumentation

The WinEPG system was used in this study [3] with the EPG sampled at 100Hz simultaneously with the acoustic signal at 22,050 Hz. To record the dynamic tongue contact patterns, each speaker had an artificial plate individually constructed to fit against the hard palate. The plate contained 62 electrodes, placed in eight horizontal rows according to well-defined anatomical landmarks with the electrodes arranged such that Row 1 had 6 electrodes with Rows 2-8 each containing 8 electrodes [4].

2.2. Procedures

In the study, each participant was fitted with a tailor-made artificial plate, wearing it for an

adaptation period of half an hour before the experimental recording commenced.

2.3. Stimuli

The vowel stimuli were /i/, /u/, /a/, embedded in a nonsense carrier phrase 'a CV papa', where CV was either pea, pah, or boo. The choice of only consonants /p/ or /b/ in the carrier phrase was to minimize the co-articulation effect of lingual consonants on the realization of the vowel stimuli. Each carrier phrase was repeated ten times, so in this experiment, 30 tokens were analysed per participant.

2.4. Participants

Eleven speakers took part in the experiment, five Scottish speakers and six Southern British English speakers. Although Scottish English has a vowel system that is different from Southern British English, we did not compare participants with different accents in this experiment.

2.5. Measurements

The EPG data were annotated in Articulate Assistant with five measurement points within each vowel stimulus. The five points were: the onset and the offset of the vowel, plus three equally spaced time intervals at $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ points through the vowel. The onset and the offset of the F2 were used to identify the beginning and the end of each test vowel and the five annotation points were used to extract the EPG values. Total contact was calculated as the sum of contacted electrodes expressed as a percentage of the total of 62. The time measurements of the five annotation points in Articulate Assistant were also extracted. These time points were then used to extract the Formant values for all the vowel stimuli in Praat [5]. The extracted Formant values were then converted into Bark scale for statistical analyses.

3. RESULTS

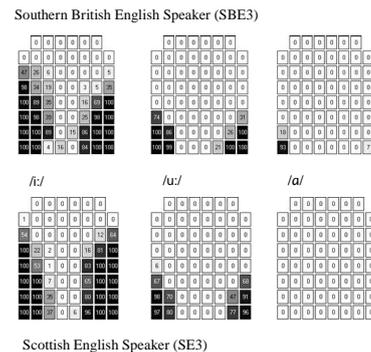
We first report EPG patterns for the vowels at the five annotation points followed by results of the relationship between EPG contact, F1 and F2.

3.1. Percent Contact

As expected, total EPG contact decreased as the vowels moved from a high/close position to a low/open position in the vocal tract. This pattern was consistent across all speakers. Figure 1

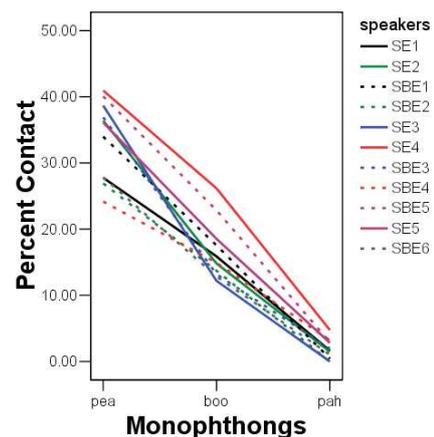
illustrates the EPG patterns for the 3 monophthongs for a Scottish and Southern British English speaker. These data show that there is a relatively long and narrow constriction during the high front vowel /i/. The EPG contact for /u/ on the other hand is shorter, more posterior and with a wider gap compared to /i/. The vowel /a/ has minimal EPG contact.

Figure 1: The EPG Patterns of the four monophthongs for a Scottish English and Southern British English Speaker.



The decrease in total EPG contact illustrated in Figure 1 was consistent across speakers, as illustrated in Figure 2, although there was considerable inter speaker variation in the amount of contact for the high vowels. For example, for /i/, speaker SBE4 had the lowest mean total contact at 24%, whereas speaker SE4 had the highest mean at 41%.

Figure 2: EPG Percent Contact of the three monophthongs across 11 speakers



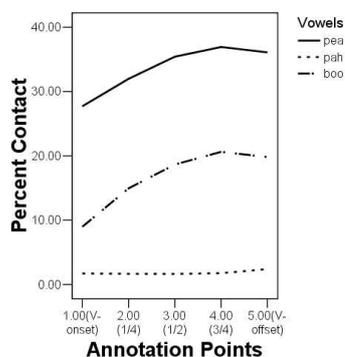
A Univariate ANOVA was conducted to test whether vowel types affected the amount of Percent Contact. The dependent variable was Percent Contact, with three independent factors –

Vowel Type(3) , Speaker (11) and Measurement Points (5). Vowel Type was found to affect Percent Contact ($F = 18406.432$, $df = 2$, $p < 0.0001$); so was the effect of Speakers ($F = 219.94$, $df = 10$, $p < 0.0001$). There was also an effect of Measurement Points ($F = 369.247$, $df = 4$, $p < 0.0001$).

There were an interaction effect between Vowel Type and Speaker ($F = 77.874$, $df = 20$, $p < 0.0001$), a significant interaction between Vowel Type and Measurement Points ($F = 88.615$, $df = 8$, $p < 0.0001$), and a significant interaction between Speakers and Measurement Points ($F = 4.101$, $df = 40$, $p < 0.0001$). There was a three-way significant interaction among Vowel Types, Speakers and Measurement Points ($F = 3.339$, $df = 80$, $p < 0.0001$). Post-hoc Games-Howell tests were conducted on the ‘Vowel Types’. All pairwise comparisons were statistically different at $p < 0.05$. All the monophthongs exhibited different amount of Percent Contact. The rank order of the Percent Contact from the highest to the lowest was /i/, /u/, and /a/. Post-hoc (Games-Howell) tests were also conducted on Measurement Points. The pairwise comparisons showed that Measurement Points 1 and 2 are statistically different from the other three measurement points in the vowels (at $p < 0.05$).

The interaction between Vowel Type and Measurement Points resulted mostly from the lack of lingual contact for the vowel /a/, as illustrated in Figure 3. The trajectory upwards of Percent Contact observed in /i/ and /u/ is interpreted as reflecting that the tongue was moving towards the intended vowel targets.

Figure 3: EPG Percent Contact at 5 Measurement Points for the three monophthongs.



3.2 Relationship between Percent Contact and F1, F2 and F2-F1 difference

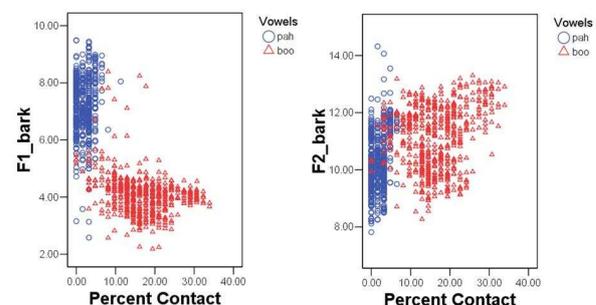
To test whether differences in EPG Percent Contact had acoustic consequences, Pearson correlation analyses were performed, with Percent Contact and F1 and F2 as variables. A statistically significant correlation was found between Percent Contact and F1 ($r = -0.701$, two-tailed, $p < 0.01$). A paired t-test also showed that the correlation was statistically significant ($t = 32.098$, $df = 1644$, $p < 0.0001$). That is, the higher the Percent Contact, the lower the F1.

The correlation between Percent Contact and F2 also reached statistical significance ($r = 0.674$, two-tailed, $p < 0.01$). A paired t-test showed a statistical difference ($t = 17.539$, $df = 1644$, $p < 0.0001$). As Percent Contact increased, so did F2. In other words, Percent Contact is correlated with both F1 and F2, though the direction of correlation in F1 and F2 was different.

However, these three monophthongs varied along two dimensions – tongue height and anteriority. It was not clear whether the variation in both F1 and F2 relative to Percent Contact was a result of the height or the anteriority of the tongue. To de-couple these two dimensions, we compared two pairs of vowels in order to keep one dimension constant at a time – a) ‘boo versus pah’ b) ‘pea versus boo’. In the first pair, both vowels were back, with a high tongue position for /u/ in ‘boo’ and a low tongue position for /a/ in ‘pah’. In the second pair, both vowels were high, but /i/ in ‘pea’ is more anterior than /u/ in ‘boo’.

For the ‘boo versus pah’ pair, Figure 4 shows that Percent Contact did not separate out the two vowels in terms of F2; however, the difference in Percent Contact resulted in separating out the two vowels in F1.

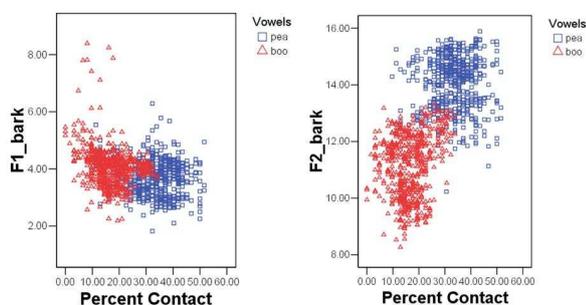
Figure 4: Correlations of Percent Contact and respective F1 and F2 (in Bark scale) for the ‘pah versus boo’ pair.



Pearson correlations showed that Percent Contact has a stronger correlation with F1 ($r = -0.777$, $p < 0.01$ (two-tailed)) than that with F2 ($r = 0.438$, $p < 0.01$ (two-tailed)). That is, Percent Contact as a result of difference in vowel height affects F1 more than F2.

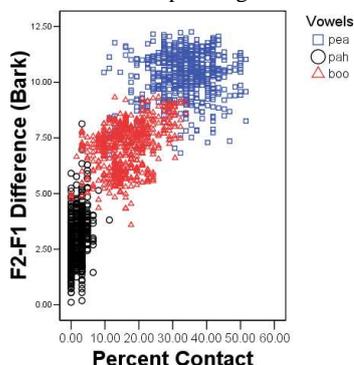
Turning to the 'pea versus boo' pair, the results in Figure 5 show that the Percent Contact correlates better with F2 than F1 in separating out the two vowels (F2: $r = 0.673$, $p < 0.01$ (two-tailed); F1: $r = -0.319$, $p < 0.01$ (two-tailed)). It suggests Percent Contact as a result of difference in anteriority affects F2 more than F1.

Figure 5: Scatter plots of Percent Contact and respective F1 and F2 (in Bark scale) for the 'pea versus boo' pair.



Pearson correlation between the F1-F2 difference and Percent Contact also yielded statistical significance ($r = 0.884$, $p < 0.01$ (two-tailed)) as illustrated in Figure 6. A paired t-test was then conducted and statistical significance was found for the correlation ($t = 36.998$, $df = 1644$, $p < 0.0001$).

Figure 6: The scatter plot of Percent Contact and F1-F2 difference for the three monophthongs.



The Percent Contact correlated strongly with F1-F2 difference, with clear separation among /i/, /a/ and /u/.

4. DISCUSSION

As expected, this study found that Percent Contact varied with /i/, /u/ and /a/. The lack of lingual contact in the low vowel correlated with a low mean F2-F1 difference (2.99). This is in contrast to /i/, where the high amount of lingual contact correlated with a much greater mean F2-F1 difference (10.38). As for /u/, where the amount of lingual contact was intermediate between /i/ and /a/, its F2-F1 difference was also intermediate (7.07). These values suggest that an increasing Percent Contact will result in greater F2-F1 difference.

The current findings showed that EPG provided us with data about the amount of lingual contact, which is a general indication of degree of constriction in the oral tract to divide up the acoustic tube into anterior and posterior resonance chambers. This constriction bears on F1, F2 and the F2-F1 difference. The EPG data also showed a high degree of lingual contact and therefore a longer and narrower constriction in the anterior part of the oral tract in producing the high front vowel /i/. This EPG contact differed from that in /u/, which showed bilateral lingual contact in the last four horizontal rows of the palate with a wider gap between. In other words, the EPG Percent Contact provided information about how the oral tract as a resonance tube is divided.

5. REFERENCES

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