EPG CHARACTERISTICS OF VELAR STOPS IN NORMAL ADULT ENGLISH SPEAKERS

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ABSTRACT

This study aimed to determine the main characteristics of normal tongue palate patterns for velar stops. EPG data from the EUR-ACCOR database were analysed for nonsense VCV sequences containing /k/ in nine vowel contexts for seven English speaking adults. Incomplete EPG closure across the palate for /k/ occurred in 19% (range 4%-41%) of utterances with the most number of incomplete closures in /aka/ and the least in /uki/. As predicted, place of articulation was dependant on vowel context. The most fronted was the velar occlusion in /iki/ and the most retracted in /aka/. In terms of amount of contact, /k/ in /iki/ environment had almost twice as much tongue palate contact compared to /aka/ in all speakers (mean 42% for /iki/ compared to 22% for /aka/). There was considerable interspeaker variability in all variables. The implications of the results for diagnosing and treating speech disorders are discussed.

Keywords: velar stops, electropalatography, occlusion, speech disorders.

1. INTRODUCTION

The notion of place of articulation has a pre-eminent status in phonetics because it identifies the location within the oral cavity at which major articulatory events occur. One important aspect of tongue placement during speech is the location of its contact against the hard palate. These tongue palate contact patterns can be measured safely and conveniently with the technique of electropalatography (EPG).

Many previous studies have investigated normal patterns of tongue palate contact for a range of lingual consonants and vowel sounds [1, 2, 3, 4]. There are fewer EPG studies of velar consonants, however, because normal adults do not always produce these sounds with contact that is registered with EPG. In particular, they may have incomplete closure registered on the palate, because the closure occurs behind the most posterior row of electrodes on the palate. Knowledge about the range of normal patterns is of central importance to speech and language therapists, however, when using EPG to treat children and adults with speech disorders.

A recent survey [5] showed that nearly a third of all individuals undergoing EPG therapy in Scotland over a 10 year period targeted /k/ during their therapy programme and it was the fifth most commonly targeted sound after /s/, /t/, /ʃ/ and /d/.

2. METHOD

2.1. Participants

The study involved the analysis of articulation data from seven normal adult speakers of English, ranging in age from 24 to 47 years and a mean of 36 years. There were four female (F1, F2, F3 and F4) and three male (M1, M2 and M3) participants. Participants were faculty members at the University of Reading, UK. They had no history of speech, language or hearing difficulties and were all native speakers of English.

2.2. Speech material

Simultaneous EPG and acoustic data were recorded as the participants read out loud a set of nonsense VCV sequences in which V represented /i/, /a/ and /u/, while C represented /k/. Ten repetitions of the word list were recorded for each speaker, thus 630 items were prepared for the analysis. Data for the velar stop were compared to data for alveolar stop /t/ where appropriate.

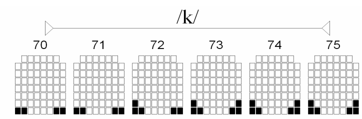
2.3. Instrumentation & recording

The speech material was extracted from the EUR-ACCOR database [6]. The data was recorded using the Reading Multi-channel System, with the EPG data sampled at 200 Hz and the acoustic signal at 20 kHz. Data were recorded in several channels, for this study only the audio signal (Sennheiser microphone MKH 40 P48) and tongue palate contact (Reading EPG system) were utilised. Data were imported into the Articulate Assistant software [7], which was used for segmentation, annotation and analysis.

2.4. Data analysis

Three variables were analysed: percent of incomplete EPG closures, place of articulation and amount of contact. The beginning of the occlusion was identified as the first EPG frame showing full electrode activation on one or more rows, with the end of the occlusion identified as the last frame of full electrode activation across one or more rows. The annotated EPG frames at the beginning and end of segments usually coincided with the acoustic events marking the beginning and the end of the occlusion phase. When there was not full electrode activation on at least one row on the palate during velar occlusion (Figure 1), the repetition was tagged "incomplete EPG closure" and annotation was performed according to acoustic events (silence in the acoustic signal).

Figure 1. EPG printout of a case of an incomplete EPG closure in /aka/ realised by the speaker F1.



Percent of incomplete EPG closures for each speaker and each vowel context was calculated. Number of incomplete EPG closures was counted for each repetition and each vowel context, divided by the total number of repetitions (10) and multiplied by 100. The data for each vowel context were averaged across speakers.

Place of articulation was measured by means of the PCoG (Posterior Centre of Gravity) at the point of maximum contact in different vowel contexts [8]. The PCoG index was calculated on the central four mid-sagittal electrodes in the back four rows according to the following formula:

(1) $$PCoG = \frac{(0.5xR8) + (1.5xR7) + (2.5xR6) + (3.5xR5)}{R8 + R7 + R6 + R5}$$

(where R8 to R5 = a number of activated electrodes in the mid-sagittal four electrodes in rows from the most posterior (R8) to a mid-palate (R5) row). A higher PCoG value indicated a more fronted articulation, while a lower value indicated a more retracted articulation.

Amount of contact was measured at the maximum contact point. It was expressed as a percent of a total number of contacts as a fraction of the whole palate (62 electrodes). So, the largest possible result was 100%, meaning all of the electrodes were contacted at the maximum contact point, whereas the lowest possible result was 0%, meaning none of the electrodes were contacted.

The statistical significance of differences between the variables was tested by means of heteroscedastic t-test.

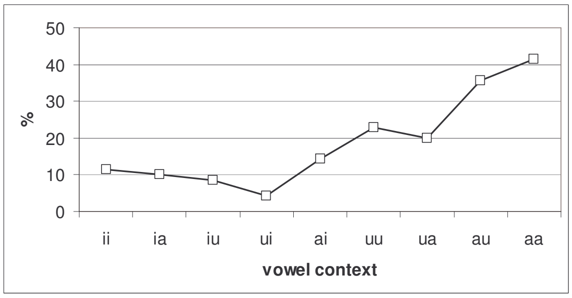
3. RESULTS

3.1. Complete vs. incomplete EPG closures

Figure 2 shows that there were cases of incomplete EPG velar closures in all vowel contexts. In total, 19% of velar stops had incomplete EPG closures, with the results ranging from 4% to 41%. The following are nonsense words ordered from the highest to the lowest percentage of incomplete EPG closures: /aka/, /aku, /uku/, /uka/, /aki/, /iki/, /ika/, /iku/, /uki/. The differences between vowel contexts, however, are not statistically significant ($p>0.05$).

The speakers also varied considerably in the number of incomplete occlusions (F1 60%, M2 26%, F2 23%, M3 11%, F4 8%, M1 2% and F3 1%). Only speaker F1 differs significantly from other speakers ($p<0.05$).

Figure 2. Percent of incomplete EPG occlusions in velar stops in nine vowel contexts.



3.2. Place of articulation

The results in Figure 3 show that the place of articulation as measured by the PCoG index at maximum contact point during velar occlusion varies depending on the vowel context. The most fronted is the velar occlusion with /i/ vowel context (/iki/ with the average PCoG value of 1.36, s.d. 0.54), while the most retracted is the occlusion with /a/ vowel context (/aka/ with the average PCoG value of 0.5, s.d. 0.01). This difference is illustrated in Figure 4. The following are nonsense words ordered from the highest to the lowest PCoG index values: /iki/, /ika/, /iku/, /uki/, /aki/, /uka/, /uku/, /aku/ and /aka/. The following differ significantly ($p<0.05$): /iki/ from /uki/, /aki/, /uka/, /uku/, /aku/ and /aka/; /ika/ and /iku/ from /uka/, /uku/, /aku/ and /aka/, while /uki/ differs only from /aka/.

A high negative correlation coefficient ($r = -0.73$) shows that data for incomplete EPG closure and data for place of articulation move together in an inversely proportional way. This means that the probability of incomplete EPG closure in the velar stop /k/ will increase in a more retracted vowel context.

Figure 3. PCoG index at maximum contact point during velar occlusion in nine vowel contexts.

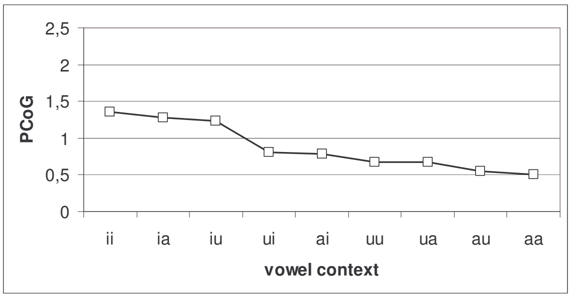
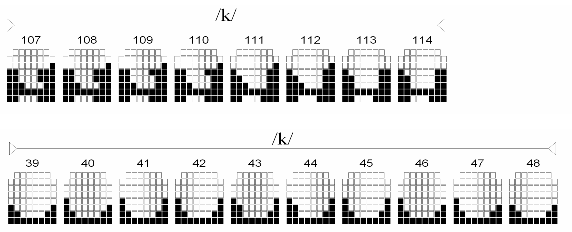
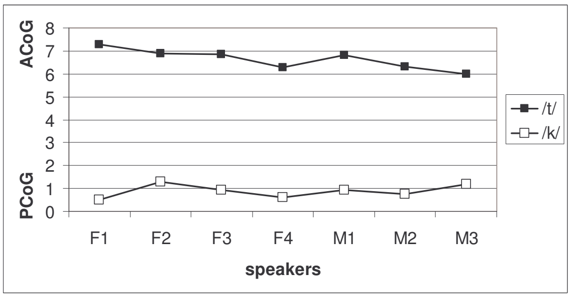


Figure 4. EPG printout of the velar closure in /iki/ (top) versus /aka/ (bottom) as realised by the speaker F3.



The distance in targets in alveolar and velar stops in identical vowel environments and for the same speakers can be seen in Figure 5. The figure does not show the actual distance on the EPG palate, but the difference between the two calculated index values: PCoG and ACoG [8]. The ACoG index for alveolar stops for the same speakers was investigated in a previous study [9]. The distance between the two occlusions is clear in all speakers, with M3 having the smallest distance (index difference of 4.81) and F1 having the greatest distance between the targets (index difference of 6.77). Average placement in velar occlusion is between PCoG values 0.51 and 1.29 (mean 0.88, s.d. 0.28) and in alveolar occlusion between ACoG values 5.98 and 7.28 (mean 6.63, s.d. 0.45). The differences between PCoG values for each speaker are all statistically significant ($p<0.05$), except between F2 and M3 as well as between F3 and M1.

Figure 5. The distance in placement at maximum contact point between alveolar and velar stops in seven speakers.



3.3. Amount of contact

Amount of contact (Figure 6) also depends on the vowel context. The amount of contact in velar occlusion ranges from 22% in the open vowel context of /aka/ to 42% in the close front vowel context of /iki/. The following are nonsense words ordered from most to least contact: /iki/, /iku/, /ika/, /uki/, /aki/, uka/, /uku/, /aku/ and /aka/. The following differ significantly ($p<0.05$): /iki/ and /uku/, /uka/, /aku/, /aka/, then /ika/ and /aku/, aka/, then /iku/ and /uku/, /uka/, /aku/, /aka/ and finally /uki/ and /aka/. There were also considerable interspeaker differences in the amount of contact (F4 22%, F1 23%, M2 26%, F3 36%, M1 36%, F2 39% and M3 42%). All the differences between speakers are statistically significant ($p<0.05$), except those between F1 and F4, F2 and M3 as well as F3 and M1. However, although overall differences between speakers are considerable, Figure 7 shows that all speakers follow the same trend.

Figure 6. Amount of contact at maximum contact point measured in nine vowel contexts.

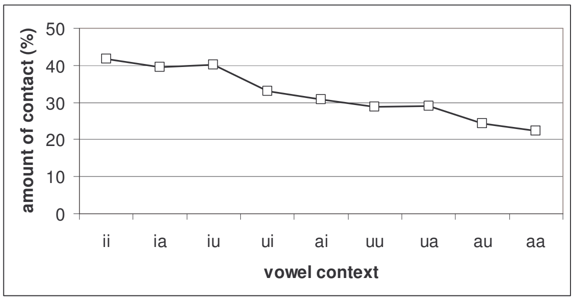
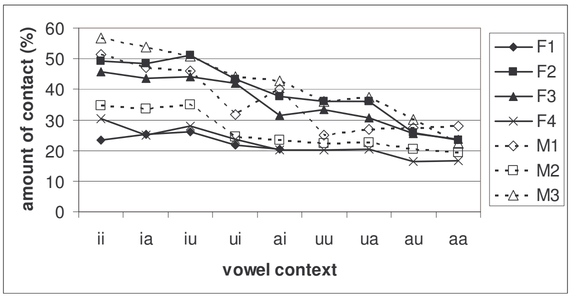


Figure 7. Amount of contact at maximum contact point measured in nine vowel contexts for each speaker.



4. DISCUSSION

The finding that up to 41% of velars have incomplete EPG closure has important implications for diagnosis and therapy. First, incomplete closures occur frequently in normal speakers and should not be regarded as an abnormal pattern. It is likely that the occlusion is occurring at a place behind the most posterior row of electrodes. During intervention, therapists should be aware of this finding, and if they are targeting velars, then a possible initial approach would be to place velars in a high vowel context when complete closure is more likely to occur. They should also expect about half the amount of contact for velars in /aka/ than in /iki/. Considerable interspeaker differences in the amount of contact during velar closure should also be kept in mind during therapy. One explanation for the differences in amount of contact is the interspeaker variations in oral morphology. A wide range of variation in the amount of contact produced by normal speakers makes it a challenge to identify abnormal patterns of contact when they occur in individuals with speech disorders. Nevertheless, the results of this study showed that although speakers vary in the amount of contact in different vowel contexts, they all follow the same trend. This is in agreement with the finding that normal speakers retain similar spatial patterns for speech sounds, although the overall amount of contact differs significantly between speakers [10].

It is also important in diagnosis to recognize the importance of the relative distance in placement between alveolar and velar targets. The results of this paper show clear separation of the place of articulation of these two targets. The relevance of this type of data is shown by a recent study that used EPG and acoustic data to investigate /t/ and /k/ targets produced by an adult with a repaired cleft palate [11]. Statistical analysis showed significant difference in COG values for alveolar and velar targets, although the perceptual analysis indicated placement neutralisation. In the case of middorsum palatal stops, which are the most frequent types of compensatory error [12], it is important to make these targets maximally distinctive by shifting the alveolar targets forward and at the same time to shift the velar targets backwards.

5. REFERENCES

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