SPEAKER CONSISTENCY OF COARTICULATORY GESTURES IN CLUSTERS OF LABIAL AND VELAR PLOSIVES

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ABSTRACT

This article describes the changes in oral pressure during [pk] and [kp] sequences in asymmetrical [i:,u:] vowel contexts as well as in symmetrical [i:,u:,a:] contexts. Observed patterns are in part similar to those described in the literature. Although speakers do exist who consistently use certain patterns in a given context, the patterns can also vary both within and across speakers.

Keywords: oral pressure, plosive clusters, speaker consistency

1. INTRODUCTION

Previous studies have shown that coarticulatory tongue movements caused by the vowel context can lead to observable changes in oral pressure, and consequently airflows similar to those in velaric suction (clicks) or pressure stops, during overlapping plosive sequences [1-4]. Like the languages investigated in these studies, Norwegian does not have genuine clicks, in which the velar closure is initiatory rather than articulatory [5,6]. But in the case of [pk] sequences, gestural overlap between the two heterorganic plosives can lead to a click-like phenomenon if the tongue moves backward during the closure for [k]. This can occur when a front vowel precedes and a back vowel follows the plosive cluster, as in [i:pku:]. If the movement is large enough to cause a rarefaction of the air trapped in the oral cavity from about lung pressure (in the [p] closure) to below atmospheric pressure level, this results in an ingressive velaric airflow at the release of the first plosive (similar in effect to a velaric suction stop). If the movement is small, the drop in pressure of the trapped pocket of air may not lead to a reduction below atmospheric pressure, so that there is no airflow or even an egressive airflow at release of the labial consonant.

Although no speech sounds with an egressive velaric airstream mechanism are known to be used linguistically in any of the world's languages, such an airflow can occur as a similar coarticulatory effect in [u:pki:] sequences, if the tongue moves forward during a period of coarticulatory overlap in the plosive cluster, since the positive pressure in the pocket of air between the two places of articulation will increase even further, leading to an egressive velaric airflow at release of the first consonant (notice that a similar, but weaker airflow should be expected even without a forward tongue movement, since oral pressure is positive in [p]).

The acoustic effect usually is not clearly audible due to auditory masking, as discussed in [4]. In [kp] sequences, similar effects to those just discussed may be present. The oral pressure in the trapped pocket of air in this plosive sequence is roughly equal to atmospheric pressure at the start of the bilabial closure (due to the preceding velar closure), so that a backward tongue movement during the overlapping stops should lead to a stronger rarefaction of the air, while the effect of a forward movement should be less than in [pk] sequences. The audible effect of both will be even less than in [pk] clusters, since the bilabial closure in overlapping [kp] blocks the transmission of acoustic energy when a pressure equalization between the oral and pharyngeal cavities occurs at the release of the velar stop.

In [1] it is noted that the patterns described in their study, which uses a single speaker as a subject, are consistent. In [2], on the other hand, it is pointed out that the extent of coarticulation can vary individually, in addition to its dependence on speaking rate. In [4], subjects were shown to differ in their acoustic realizations of the /tg/ sequence in the utterance fragment *"mit grauem"*, but there were no repetitions of the stimulus within a subject, so that within-speaker consistency could not be evaluated. In a study of the production of velar consonants, within-speaker consistency was high, but different speakers used different motor patterns [7]. The present study describes the results of a pilot experiment on the consistency in interarticulatory timing of the gestures under discussion within and across speakers, and their effect on the oral pressure signal.

2. METHOD

Two possible measurement types were considered for the present study. Since measurement of the ingressive and egressive airflows of interest in this study result in artefacts (below), oral pressure measurements were used (Section 2.1). The stimuli and subjects are described in Section 2.2.

2.1. Airflow versus pressure measurements

As others have noted [8,9] the measurement of the secondary airflows of interest with a pneumotachograph "Rothenberg" mask [10] can be distorted by the effects of tissue movement in the mask due to articulatory movements of the jaw and lips, which can change the volume of air in the mask itself. In preliminary experiments we found that these artefactual airflows can be of the same size as those caused by coarticulatory tongue movements. We therefore decided not to directly measure ingressive and egressive airflows, and instead reverted to the use of oral air pressure measurements, as in [1]. The pressure HD-10A transducer which the Rothenberg mask is equipped with was used for oral air pressure recordings (but note, without using the mask itself). In our experiment, oral pressure recordings were obtained by means of a customized mouth piece attached to a small plastic tube that was connected to the pressure transducer, the mouth piece preventing blockage of the tube by saliva or contact with tissue. The plastic mouth piece was placed between the cheek and the teeth, recording the oral pressure in the cavity behind the lips.

The signal was digitally converted with an amplitude resolution of 16 bits and at a sampling rate of 10 kHz, after low-pass filtering at 5 kHz.

2.2. Stimuli and subjects

To be able to measure oral pressure, voiceless clusters consisting of a labial and a velar stop were used. As in [1], the clusters were produced in VCCV tokens in which the cluster was flanked by symmetrical and non-symmetrical vowel combinations /i:_i:, u:_u:, a:_a:, i:_u:, u:_i:/.

Because the particular clusters seldom occur in actual words, and because actual compounds would only cover a few of the contexts, nonsense compounds that consisted of two actual words were employed, e.g. /pi:p#ku:n@/ ("beep"#"wife"). Since the voiceless velar plosive is realized as a palatal fricative /C/ in Norwegian when it precedes /i:/, the common English loanwords "kick" was used (with a short vowel), since here the /k/ is realized as a plosive.

The compounds were produced in the carrier phrase *"Der sa du <test word> igjen."* ("There you said <test word> again"). A carrier phrase was used to prevent hyperarticulated realizations of citation forms. The subjects were encouraged to speak in a relaxed, everyday manner. Subjects produced the ten test words (two consonant clusters x five vowel contexts) in six randomized lists that each included two initial and one final filler. If needed, further instructions were given after the first list, which was omitted from analysis. All participants (five women and three men) were from the Trøndelag area, and were between approximately twenty and thirty years old.

3. RESULTS

In the following subsections the most conspicuous oral pressure patterns in different consonant clusters in asymmetrical (different vowel) contexts will be described and compared with the same clusters in symmetrical (same vowel) contexts. Since the oral pressure recordings of two of the female speakers appeared unreliable in a large majority of the stimuli, these two subjects were discarded.

3.1. [u:pki]

The strongest effects, in terms of the size of the change in oral pressure, are found in clusters with an asymmetrical vowel context. In realizations of [u:pki] a tendency for a further increase in oral pressure during the second half of the labial closure can be observed (after point A in Figure 1). Notice that the increase varies strongly across tokens, both in size and duration. Often there is a strong peak only just before the release of the labial closure (point B). Presumably the start of the increase marks the start of contact of the velar stop, which overlaps with the preceding labial stop. The increase in oral pressure is interpreted as the result of a forward tongue movement: Since the back of the tongue is moving from a back to a front place of articulation for the vowels, the velar contact area slides and/or expands forward across the roof of the mouth, causing a reduction in volume of the oral cavity and an increase in pressure. In addition, the closing movement of the jaw during the first part of the consonant cluster may cause a further

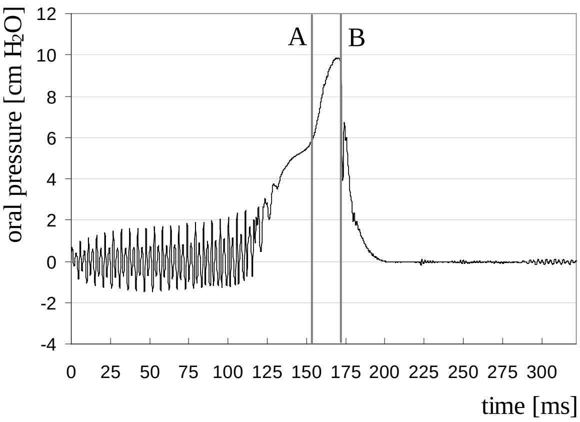

Fig. 1: Oral pressure signal for **[u:pki]** for speaker F2

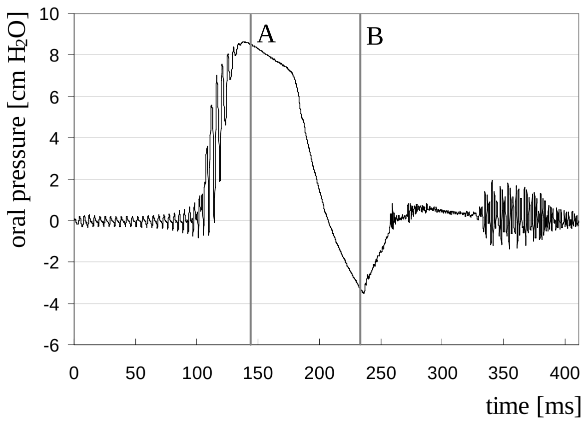

Fig. 2: Oral pressure signal for **[i:pku:]** for speaker F1

reduction of the oral cavity volume towards the end of the labial closure. The observed pattern is typical for this particular context, in which it is found in 46.7% (14 out of 30) of the cases, while it only occurs in 1.5% of the remaining 270 contexts (cf. Table 1). For one of the speakers, a considerable oral pressure increase occurs consistently in all five realizations of the stimulus, while for most others this pattern is observed in some but not in other realizations. For some of the realizations, a rounding of the plateau can be observed towards the end of the closure, which is contrary to the pattern described above. Since no articulatory explanation for this pattern seems readily available, a possible cause in the measurements may have to be considered, namely a slight break in the bilabial closure possibly caused by the pressure tube. In other contexts, the pattern only occurs in three tokens for subject (F3) and in one token for M2, all in a symmetrical [u:] context.

3.2. [i:pku:]

A comparable, but opposite effect may be expected in [i:pku:] stimuli, since the vowel context in this case requires a backward movement of the tongue body, causing an expansion of the oral cavity and thus a decrease in oral pressure. It may be counteracted somewhat by the closing movement of the jaw required for the articulation of the consonant cluster. But note that a subtraction of a similar peak from the plateau as in the [u:pki] stimuli but now with an opposite effect (i.e. causing a reduction of the oral pressure during the second half of the closure, after the start of velar contact, presumably as early as point A in Figure 2) is not nearly as visually conspicuous: It usually shows up as a strong rounding of the pressure plateau in [p] towards the release or, alternatively, as a negative slope during the pressure plateau (notice that this pattern was also sometimes observed in [u:pki] stimuli, but described as an artifact of the measurements), with a usually small but consistent negative peak directly after the labial release. As explained in the Introduction, the pressure, which reaches lung pressure level shortly after the beginning of the labial closure, does not have to go below the level of atmospheric pressure due to the backward movement of the tongue. In fact, it only does so in 50% of the [i:pku:] stimuli (while a negative pressure *never* occurs in any of the other [VpkV] stimuli). Only in some cases does the negative pressure show a clear dip (a relatively extreme example is given in Figure 2 as a demonstration of this pattern, with a wide dip around point B, cf. also [1]). The negative pressure is caused by a strong backward movement of the tongue body, possibly supported by a slight opening of the jaw.

Table 2: Percentage scores for frequency of occurrence of the particular pressure patterns described in the text for each of the four selected stimuli (cf. Figures 1-4 for an example of each pattern) for all speakers and across speakers.

context	n	M1	M2	M3	F1	F2	F3	*total*
[u:pki]	5	20.0	40.0	40.0	20.0	100.0	60.0	46.7
other	*45*	*0.0*	*2.2*	*0.0*	*0.0*	*0.0*	*6.7*	*1.5*
[i:pku:]	5	80.0	40.0	20.0	60.0	60.0	40.0	50.0
other	*45*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
[u:kpi:]	5	40.0	60.0	100.0	80.0	100.0	60.0	73.3
other	*45*	*8.9*	*2.2*	*2.2*	*4.4*	*4.4*	*15.6*	*6.3*
[i:kpu:]	5	20.0	0.0	80.0	40.0	0.0	0.0	23.3
other	*45*	*0.0*	*2.2*	*0.0*	*0.0*	*0.0*	*0.0*	*0.4*

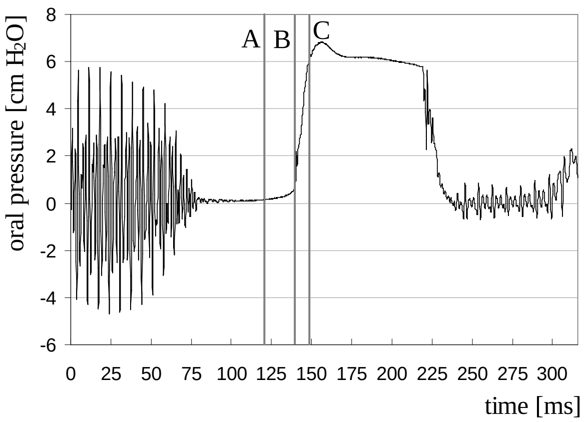

Fig. 3: Oral pressure signal for **[u:kpi:]** for speaker M1

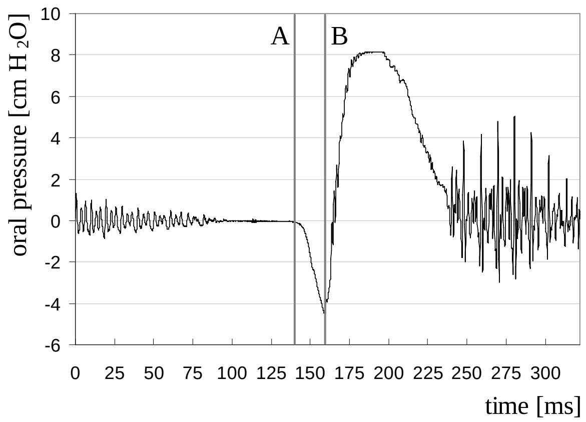

Fig. 4: Oral pressure signal for **[i:kpu:]** for speaker M3

3.3. [u:kpi:]

In [u:kpi:] stimuli, where the same forward tongue movement is required by the vocalic context as in the [u:pki] stimuli described at the beginning of this section, an increase in oral pressure during the overlapping velar and labial closures can be expected. A typical example of the pattern is shown in Figure 3. In many of the stimuli can a slight increase in oral pressure (point A) be observed even before the start of the steep slope indicating labial closure for [p] (point B), followed by a positive peak at the beginning of the plateau for [p] (point C), varying in size. As before, the pattern occurs regularly (in 73.3% of the [u:kpi:] stimuli, while it only occurs in 6.3% of all other contexts) but not consistently across all speakers. For two of the speakers, a peak is found consistently in all five realizations of this context (M3 and F2).

3.4. [i:kpu:]

The same backward coarticulatory tongue movement as in [i:pku:] stimuli can sometimes cause a strong negative pressure just before the release of the velar closure (and after the inferred labial closure, at point A in Figure 4) in [i:kpu:], directly followed by an increase in oral pressure when the velar closure is released, while the labial closure remains (point B). This pattern is related to a backward movement of the tongue to implement the front-to-back vocalic gesture during the period of overlap between the labial closure and the velar release. Although not consistent for this stimulus (it only occurs in 23.3% of the [i:kpu:] stimuli), the pattern is typical for this context and only occurs once in the other stimuli. Three speakers (M2, F2, F3) consistently do not use this pattern for [i:kpu:].

4. DISCUSSION

The observed oral pressure changes in clusters of labial and velar consonants show similar patterns to those previously observed in the literature. But although there is some indication of speaker-specific articulation strategies, the observed patterns are often variable, at least in some speakers, as they are across speakers. We should bear in mind, of course, that the tube connected to the pressure gauge can cause an impediment to natural articulation, even if care was taken to minimize its effect. Further study, preferably including pressure measurements in the pharyngeal cavity as in [1], should be carried out to obtain more data, both within and across speakers.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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