Lip gestures in Danish vowels: Articulation and coarticulation

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This paper presents the results of a pilot experiment on measuring lip gestures for the vowels of one Danish speaker (the author) including data on anticipatory lip rounding over a gradually shortened sequence of consonants in conjunction with a word boundary. The results may have implications for theories concerning coarticulation.

1. Introduction

The inspiration for this pilot investigation was a request for a description of prototypical lip gestures in Danish vowels needed for the implementation of a lip-reading training system in Danish and an unsettled debate on the degree of lip rounding for [ʌ]. Though the lips are easily accessible to observation and measurement, compared to other articulators, the visual inspection of film or video recordings is a slow and cumbersome process that greatly limits the amount of material that can be investigated. It also imposes limitations on measuring accuracy since the three-dimensional reality is recorded as two-dimensional images. Therefore access to a sophisticated 3D-tracing system located at the University of Linköping, is what made this investigation possible.

The system is best described as an automated stereometric measuring system, which tracks the spatial position of a number of small dome shaped reflectors fastened to the object whose motions one wants to capture. The position of the reflectors are measured 60 times per second and are stored on a computer synchronized with an audio recording of the speaker. Even though the domes have a diameter of three mm, their position is determined with an accuracy of 0.1 mm. Figure 1 shows the position of the measuring points used in this investigation. The glasses follow the head movements, and thus provide reference points to filter out head movements from other gestural movements.

According to the literature on lip rounding (e.g. Farnetani 1999), the width of the lip opening correlates well with other lip rounding measures. The best approximation to measuring that width is to place measuring points at the corners of the mouth. In addition, I wanted to obtain an approximation of the degree of opening which called for points on the upper and lower lip cf. fig. 1. Placing two measuring
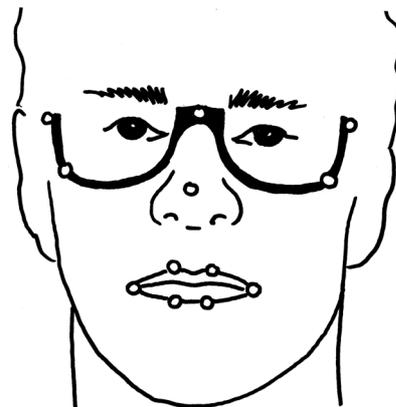

Figure 1. Position of measuring points.

points on each lip provides a better approximation to the area of the actual orifice which I expected to be of interest.

The investigation is based on read material. 46 different sentences, designed to elicit 25 different long and short vowels in comparable surroundings, as well as variations on a segmental theme to explore the degree of anticipatory rounding over a word boundary, plus a number of other related issues that are not dealt with here, were recorded 8-12 times in pseudorandomized order by the author.

2. Lip gestures in Danish vowels

Fig. 2 presents the averaged measurements of the 25 vowels. For the front unrounded vowels there is a tendency towards an inverse relation between lip-width and lip-height. This is not surprising since the lips have limited elasticity. All differences in lip gestures between neighbours in the same series are statistically significant ($p<0.05$ or better, one tailed t-test), except for for [ɛ] and [a]. The recordings of this investigation have not yet been subject to acoustic analysis to determine whether these two are also acoustically similar. But a new acoustic investigation of the Danish vowel system (M. Ejstrup & G. F. Hansen, forthcoming) indicates that a restructuring of the upper left quadrant of the vowel space is under way, and for some speakers some phonemes in this area merge. The finding of a lip gestural "merger" in this area is thus in accordance with other acoustic findings. The peculiar clustering of [eː][ɛː] and [æː] with small but significant differences in either lip height or lip width ($p<0.05$ or better, one tailed t-test) also points to such a restructuring.

In general the difference between the rounded and the unrounded vowels is largely as expected. The relations between the various rounded vowels are less obvious. It is interesting to see that [o] appears to be more rounded and more closed than [u]. There also seems to be a difference in degree of rounding for the long rounded front vowels [œː œ:] which is un-expected. Regarding [ʌ] it seems to be con-siderably less rounded than [ɔ] although it does not quite reach the lip width of the un-rounded front vowels. The average horizontal distance between the measuring points in the corners of the mouth is about the same as that of [ɑː]. However, if you compare the two photo-graphs in figure 3 of a static pronunciation of [ʌ] and [ɑː], you will see that the distance
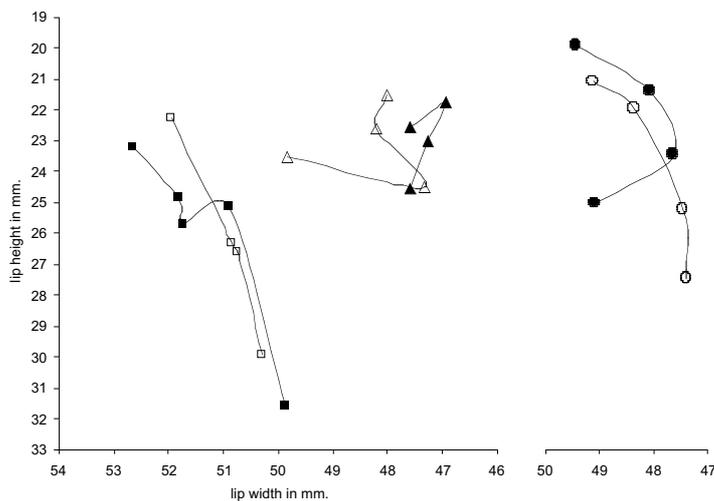

Figure 2. Two plots showing the average lip width and height measured for the 25 vowels investigated. Filled squares: [iː eː ɛː æː ɑː] Open squares: [i ɛ a ɑ] Filled triangles: [uː oː ɔː ɒː] Open triangles: [u o ɔ ʌ] Filled circles: [yː øː œː œ :] Open circles: [y ø œ œ] Vowel height increases from bottom to top. Note the two x-axes.

Figure 3. Photographs showing a static pronunciation of [ʌ] and [ɑ:], respectively.

between the measuring points (marked as black dots on the skin) does not truly reflect the actual horisontal aperture. This is a limitation of the method since it is impossible to guarantee that a given point on the lips will actually be on the border of the lip opening. The consequence is that the apparent difference between rounded and unrounded vowels in my results are reduced to the point where [ʌ] and [ɑ:] appear to have the same degree of lip rounding. But since there is no other overlap, it can still be used as a means to distinguish rounded from unrounded and to compare the degree of rounding for rounded vowels. Further analyses, however, of this material will hopefully yield some information on the degree of lip protrusion which may prove to be a more reliable rounding measure.

3. Coarticulation

The purpose of the coarticulation experiment is to see whether and how the anticipatory rounding before a rounded vowel changes as a consonant cluster is gradually reduced. The material consists of a number of sentences that provide a pragmatically and phonetically similar context to a consonant cluster of varying size. The sentences are of the type *man kan let finde skruerne i skuffen* 'you can easely find the screws in the drawer'. The constant part is *finde*, which is in all cases pronounced with a syllabic nasal, and the rounded vowel after the consonant cluster. The utterances are compared by taking measurements at the boundaries between adjoining segments as well as in the middle of them. In the case of stops, one measure is taken at the closure and one at the release. The consonant could not be kept constant through all the sentences, but none of them required labial articulation. The target vowel changes from [o] to [u] in the absence of /r/ due to an allophonic rule and there is accordingly a slight change in "target" rounding. The sentence with the unrounded target vowel serves as a base of reference. Fig. 4 depicts the results. Here is a key to the to the timing of the measures:

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   f   i   n   s   t   r    i
   f   i   n   s   k   r    u                    f   i   n   d   u
   1 2 3 4 5 6 7 8 9 10 11 12 13 14             1 2 3 4 5 6 7 8 9 10 11

   f   i   n   d   r    u                        f   i   n   u
   1 2 3 4 5 6 7 8 9 10 11 12                    1 2 3 4 5 6 7 8 9
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It appears that measurements from one through six are identical, i.e. the word boundary effectively blocks any anticipatory lip rounding. Of course this boundary is simultaneously a syllable boundary, but whether word internal syllable boundaries would exhibit the same blocking effect is an open question.

A recent paper on the trough effect (Lindblom et al., 2002) deals with the adequacy of two competing co-articulation models: a 'co-production' model versus an 'overlapping segments' model. The authors reject the co-production model in favour of the 'overlapping segments' model, even though one of their experiments shows a syllable boundary dependency which, in my view, is neither predicted nor supported by that theory. Likewise, it is hard to explain the apparent borderline for the anticipatory lip rounding that I find in my experiment as a consequence of "segments meeting". For this reason I would like to question the (general) validity of the 'overlapping segments' model and suggest a limiting of its domain of application to a smaller unit, possibly a syllable or a word. Another possibility is that the coarticulation might be just as carefully planned and controlled as the articulation of the segments' primary features.
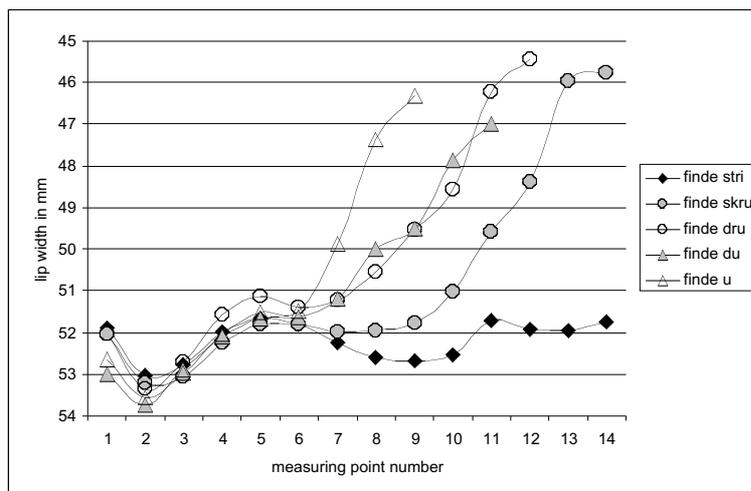
Figure 4. Average values of the five sentences used in the coarticulation experiment.

4. Acknowledgements

5. References

B. Lindblom, H. M. Sussmann, G. Modarresi, E Burlingame (2002) The trough effect: Implications for speech motor programming, *Phonetica,* 59, 245-262.

Ejstrup, M. & Hansen, G. F. (forthcoming) Danish vowels, a comparison of three regional variants, in *Proceedings of the 15th international congress of phonetic sciences*

Farnetani, E. (1999) Labial coarticulation. In *Coarticulation. Theory, data and techniques* (W. J. Hardcastle & N. Hewlett, editors), pp. 144-163. Cambridge: Cambridge university press.