Methodological Studies of Movetrack: Coil placement procedures and their consequences for accuracy.

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ABSTRACT
This article concerns the exprimental estimation of the accuracy of an electromagnetic transduction system. This system was designed for the observation and meausurement of articulatory movements in speech. The results show that Movetrack's accuracy and ease of handling make it a potentially useful research tool.

INTRODUCTION AND BACKGROUND
The advent of electromagnetic transduction techniques in speech production research appears to be a significant contribution to the methodological arsenal in this field. Crucial to the present and future use of this method in speech research is the current work on the accuracy and reliability of the data obtained with the systems now available. This study will focus on the most important technical mesurement problem , that of receiver coil tilt, especially those coils placed on the tongue.

Measurement error due to coil tilt
There are several possible causes for measurement error due to tongue coil tilt. First the plasticity of the tongue (Stone, 1992) and the resulting variation in its surface configuration. Second, pulling forces on the wire connected to one end of the receiver coil may cause tilting of the coil. Third, contact with the palate during the production of high vowels and palatal consonants may exert forces to tilt the coil.

Computer simulation of the effect of tilt correction
There are, at present, three commercially available systems. Two of these, the Carstens Electromagnetic Articulograph (EMA) (Schönle et al., 1987, and the Electromagnetic Midsagittal Articulometer (EMMA) (Perkell, et al. 1992) have an automatic tilt correction. The third device, the Movetrack (Branderud, 1985), has no tilt correction.

As a preliminary criterion for the comparison of these systems with regard to the measurement error caused by coil tilt, a computer simulation of the tilt correction was carried out.

The results of this simulation show that the effectiveness of the tilt correction increases with proximity to the midsagittal plane. Further, if the deviation from the midsagittal plan is 3 to 5 mm., a coil tilt of 10 degrees will result in approximately the same measurement error as a coil tilt of 20 degrees with tilt correction used in this simulation..

METHODS
The key assumption in these experiments was that an accurate estimation of the tilt angle during the static pronunciation of speech sounds would be a reasonable starting point for assessing the error due to tilting during running speech.

The Experimental Hardware
To be able to measure the tilt around the x and y axes we made some additions to the Movetrack system (Branderud, 1985, 1993, et al) for the experiments reported here. The experimental helmet and the coil placements are seen in figures 1 and 2.

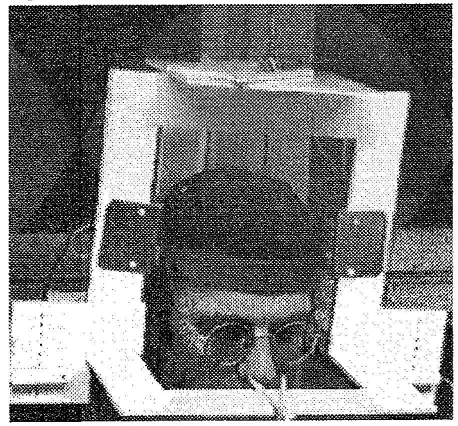


Figure. 1. *Helmet used in setup.*

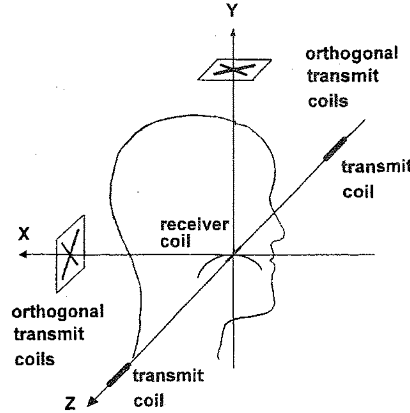


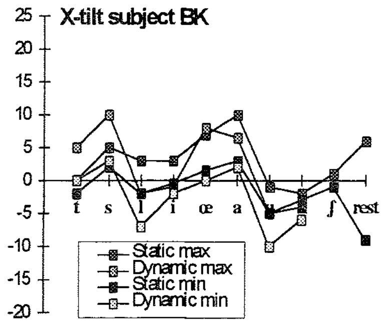
Figure. 2. *Coil placement.*

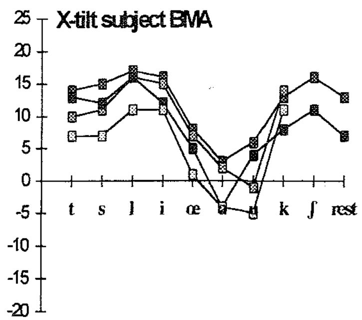
Estimation of tilt angle during static articulation
To find the coil tilt during static sounds we proceeded as follows: When transmitter coil and receiver coil are in parallel the output from the receiver coil shows a minimum. This could be used to find the tilt of the receiver coil. Instead of using the minimum, we used the maximum which occurs at 90 degrees tilt. By using the maximum, which enhances precision, we could easily measure the tilt with an accuracy of more than one degree. The transmitter coil can be rotated around its axis. The coil was placed on a protractor on which the tilt can be read. The output of the receiver coil was shown on an oscilloscope. During the static pronunciation of the phoneme, the transmitter coil was rotated until the maximum distance was found. The maximum was recorded for about five seconds and then the mean value of the five seconds was calculated.

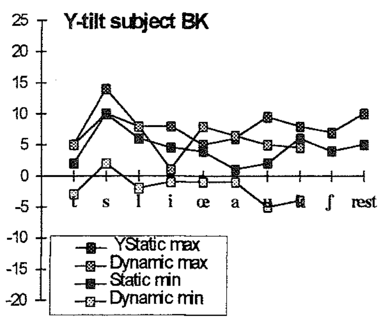
Tilt estimation in running speech
Here we used the data files with the recorded output from all coils. We used a computer to calculate the tilt angle and true position of the receiver coils.

The data was analyzed with the help of the PHYS program. This program can scale and plot the labeled data. It also calculates and plots mean values, and can display the movements in XY-plots.

RESULTS
In this paper we have chosen, because of lack of space, to present two representative subjects. For a complete report on all five subjects see Branderud, et al. (1993). In figures 3 and 4 the maximum and minimum values of the tilt-range are plotted for both the static and the dynamic sounds. The coil tilt for the dynamic sounds follows that of the static sounds quite closely. In







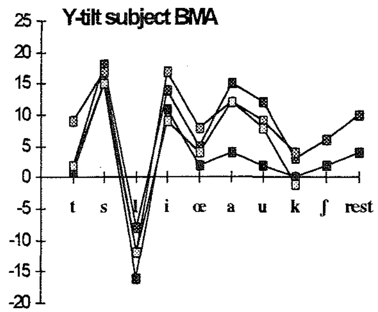
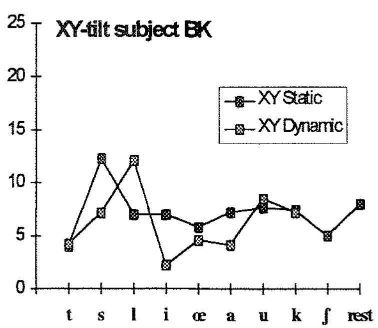


Figure 3a-b. *The maximum and minimum values of the tongue tilt range plotted for static and dynamic sounds*

Figure 4a-b. *The maximum and minimum values of the tongue tilt range plotted for static and dynamic sounds*



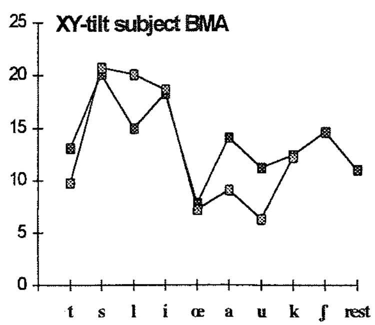


Figure 3c. *Mean of tongue tilt, plotted for static and dynamic sounds*

Figure 4c. *Mean of tongue tilt, plotted for static and dynamic sounds*

most cases the range for the dynamic and the static sounds overlap. The difference between the static and dynamic sounds is in most cases much smaller than the total tilt range.

DISCUSSION

The central issue that has been tested in these experiments is the validity of the assumption that the static and dynamic productions will display approximately the same degree of coil tilt. The

data obtained in these experiments show a fairly good match between tongue coil tilt during a temporally extended production of a sound for which the articulators are held in a static position and coil tilt during the pronunciation of this same sound in kontext. It is important to point out that the study of the timing of the movements of the articulators with the Movetrack or any other magnetometer is only marginally effected by receiver coil tilt. There are, however, obvious experimental situations in which the use of the Movetrack or any magnetometer system should be undertaken with utmost caution.

How, then, does the tilting of receiver coils effect movement data collected with these coil settings? For subject BK the maximum tilt was 12 degrees. This corresponds to a maximum absolute error range of 1.4 mm or +-0.7 mm.. Perkell et al. (1992) reasoned that the ..."desired measurement resolution should be better that the minimum displacement which could produce a perceptually salient change in the acoustics of a cardinal vowel sound." As an example he cites the case of the vowel [i], probably the most extreme case in terms of the accuracy requirement, for which this desired resolution should be -+0.5 millimeters.

CONCLUSIONS

The experimental results obtained here would seem to indicate that the method suggested in this paper for estimation of coil tilt can be used for the enhancement of the accuracy and hence the utility of the Movetrack.

ACKNOWLEDGEMENTS

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