Experimental approaches in electromagnetic articulography

Teja Rebernik[1], Jidde Jacobi[1,2], Roel Jonkers[1], Aude Noiray[3,4], Martijn Wieling[1,4]
[1]University of Groningen, [2]Macquarie University, [3]University of Potsdam, [4]Haskins Laboratories

Introduction

Electromagnetic articulography (EMA) is a point-tracking method for the study of speech kinematics, whereby sensors placed on the articulators (e.g., tongue, lips and jaw) track their 3D movement in real time. While EMA data has high spatial and temporal resolutions, there are limitations to how many sensors can be placed and where (e.g., it is more difficult to place sensors more posteriorly on the tongue) (Schönle et al., 1987; Mennen et al., 2010; Hoole & Nguyen, 1999). Consequently, the success of EMA greatly depends on accurate and durable sensor placement. The goal of our study was twofold. First, we reviewed how researchers have previously described EMA data collection procedures, with a focus on sensor placement. Second, we carried out an experiment to compare three approaches for attaching sensors to the tongue.

Literature review

For the first part, we used Google Scholar to collect journal papers and conference proceedings papers by employing the search terms “electromagnetic articulography” and “electromagnetic midsagittal articulography”. We excluded papers that were less than 4 pages long, papers that did not describe studies with participants, and papers that were not written in English. This search criteria led to 626 found papers (including 332 journal papers), in which we identified the following parameters: type of EMA device in use, number of participants, population (healthy versus pathological), total number of sensors, number of tongue sensors, placement of sensors, sensor preparation, and adhesive used for sensor placement. Regarding participants, we found that around 75% of studies tested 10 participants or fewer, and that 80% of the studies focused on healthy adults. Due to high time demands of the method, a limited number of participants is to be expected, but also highlights the need for comparable and articulatory-driven sensor placement across participants.

In regard to tongue sensor placement, we found that the most frequent choice is to place three sensors (49% of studies), from the tongue apex to the root along the median sulcus. The exact placement strategies differ, however. Some researchers choose to place sensors equidistantly, for example with 1-2 cm between the sensors. Others prefer placing the tongue tip sensor 1 cm behind the tongue apex, the tongue back sensor “as far back as comfortable” and the remaining sensor midway between the two. However, it is often unclear how exactly the placement for the tongue tip sensor is measured (e.g., with a ruler versus “eyeballing”) nor is it specified how the degree of participant’s comfort is determined. Our literature review thus demonstrated that experimental designs greatly vary across empirical studies. This discrepancy is likely to impact how speech sounds are examined and hence limit researchers’ ability to compare results across studies.

Sensor placement

For the second part, we evaluated three approaches for attaching (NDI Wave) EMA sensors with respect to the duration the sensors remain attached to the tongue. Specifically, we adhered out-of-the-box sensors (Fig. 1 left), sensors coated in latex (Fig. 1 center) and sensors coated in latex with an additional latex flap (Fig. 1 right).

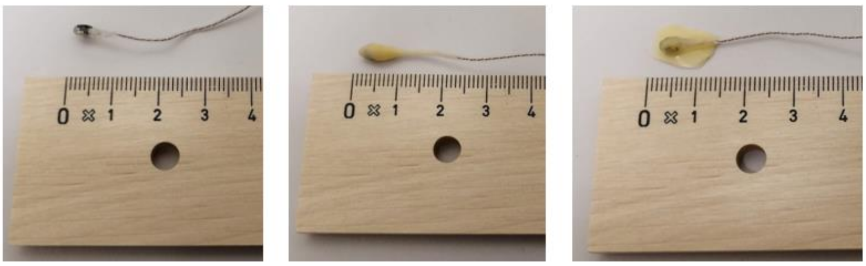

Figure 1: Sensor types (from left to right: out of the box, latexed, latex flap), next to a metric ruler.

While the first two types of sensors are frequently used, the additional latex flap, which increases the adhesion surface, is not often mentioned. Notable exceptions, which also increased the sensor surface but using a different approach, include Ji, Berry & Johnson (2013) and Goozée et al. (2000) who placed pads of silk cloth between the sensors and lingual surfaces; and Wieling et al. (2015) who glued a transparent layer of plastic to the bottom of the sensors.

We tested ten female participants, aged between 20 and 30, across three separate sessions. We adhered five sensors to the tongue using PeriAcryl®90 HV, with the tongue tip sensor placed 1 cm from the tongue apex (measured with an outstretched tongue, using a ruler), the tongue back sensor positioned at the marked place of the /k/ constriction, and the tongue middle sensor positioned halfway between the two. The participants read out a text for sensor habituation, then proceeded with reading aloud a wordlist and performing a syllable repetition task. The experimental procedure was terminated when all sensors fell off or when the tasks were repeated twice (approx. after 45 minutes). Using linear mixed-effects regression modelling, we evaluated whether sensor preparation type (Fig. 2, left) and sensor position (Fig. 2, right) affected sensor adhesiveness. The best model for our data, determined via model comparison, only warranted the inclusion of the distinction between the TB sensor and other sensors, in addition to a by-subject random intercept and a by-subject random slope for the contrast between the TB and the other sensors. Specifically, this model showed that the TB sensor adhered approximately 14 minutes less than the other sensors ($\beta = -14.0$, $t = -5.0$, $p < 0.001$). Sensor preparation type did not reach significance in the best model.

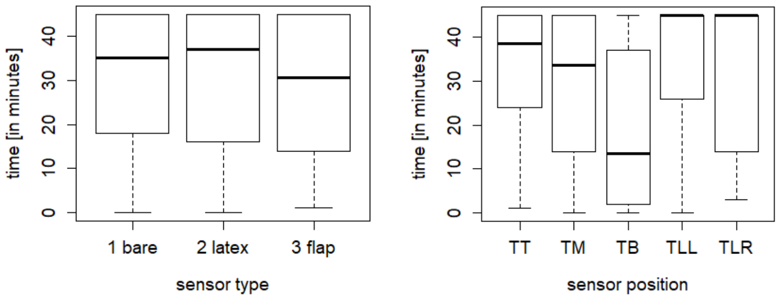

Figure 2: Effect of sensor preparation type (left) and sensor position (right) on adhesiveness.

To conclude, our findings drawn from our literature review and empirical investigation offer possible strategies for sensor placement and emphasize the importance of ensuring cross-study comparability.

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