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Jaw movements in speech during physical activity

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Speech production is affected by physical activity. Here we test how it affects German vowels that vary in openness (a e i). Our results show that jaw opening, F1, F2, and jaw/F1 correlation are affected by exercise, but how depends on the vowel.

Fig 1. MARRYS helmet for mechanical measure of jaw displacement (jaw openess). Developed by All Good Speakers/SDU.

Background

Talking while walking is an ecologically meaningful situation that can shed light on speech–motor interactions.

Physical activity diversely affects speech, e.g., f0 [e.g., 1], pause placement [2], and voice quality [3] but little is known about effects on articulation.

Articulation could be affected because exercise increases respiration – to facilitate airflow, speakers may increase oral aperture.

Ongoing acoustic work on **German vowels** shows that speech during activity has higher average F1 across vowels compared to speech at rest, suggesting a lower tongue/jaw position. This pattern is also seen in loud speech [4, 5]

Degree of **jaw opening** (jaw displacement) has intrinsic vowel effects: the jaw is more open in open vowels and less open in closed vowels [6, 7]

This pilot study thus aims to investigate:

→ Is increased F1 correlated with greater jaw displacement in speech during exercise?

To test this, we are using the **MARRYS** helmet (Mandible-Action-Related Rhythm Signals), developed by All Good Speakers and SDU. The MARRYS can record jaw movements in naturalistic settings [8]. It captures vertical movements of the jaw via bending sensors above elastic bands on either side of the face (Fig. 1). After signal postprocessing in Audacity [9], jaw displacement is obtained via min./max. amplitude in a segment using Praat [10] (Fig. 2).

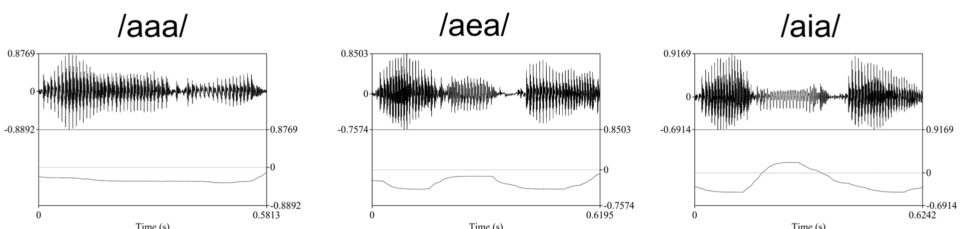

Fig 2. Sound and MARRYS signals of the isolated vowels used in the study.

Method

Acoustic and jaw (MARRYS) data recorded at the CIE Acoustics Lab at SDU (Fig. 3)

Speakers read stimuli (1) while standing still and (2) while completing a walking workout video.

Short and long stimuli sentences were used to isolate vowels /a e i/ in connected speech:

Den Flughafen AEA mag ich nicht.
I don't like AEA airport.
Den Flughafen AIA in Schweden mag ich nicht, weil er so langweilig ist.
I don't like AIA airport in Sweden because it is so boring.

6 speakers (3 female) produced 5 repetitions of each vowel in 2 conditions = 471 observations

Vowels /a e i/ were delimited in Praat [10] and mean F1 and F2 were extracted using VoiceSauce [11] implemented in MATLAB [12] using speaker- and vowel-specific formant ceilings [13]; f0 range was 80–250 Hz for males, 130–300 Hz for females.

Analyses were conducted in R [14].

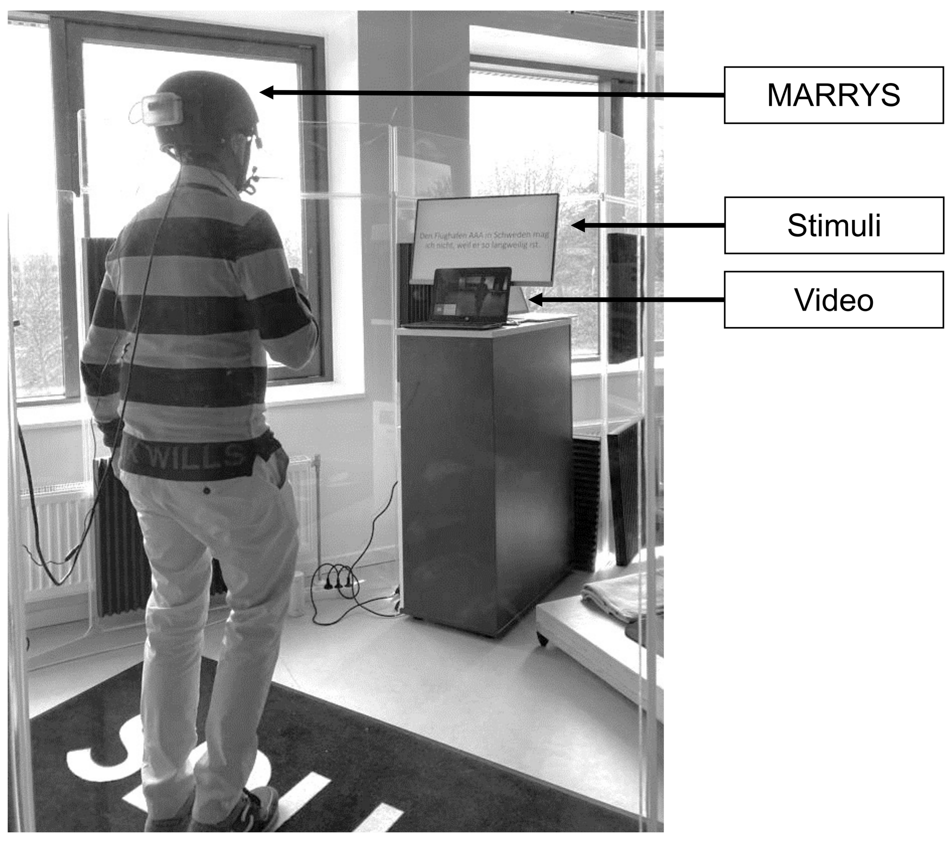

Fig. 3. Experimental setting

Results

Jaw displacement: during exercise males showed lower jaw in /a/, but higher jaw in /e i/ (Fig. 4). Females showed higher jaw in /i/ (and slightly higher in /a/), but a lower jaw in /e/.

Formant frequencies: during exercise most speakers showed higher F1 for /a/ but results were mixed for /e i/ (Fig. 5). F2 was higher in /a/ but lower in /e i/ (Fig. 6).

Correlations between jaw and F1 were negative for male speakers in /a/ and during exercise in /e/ and for females during exercise in /a/ (Fig. 7). Females showed positive correlation in /a/ and during exercise in /e/.

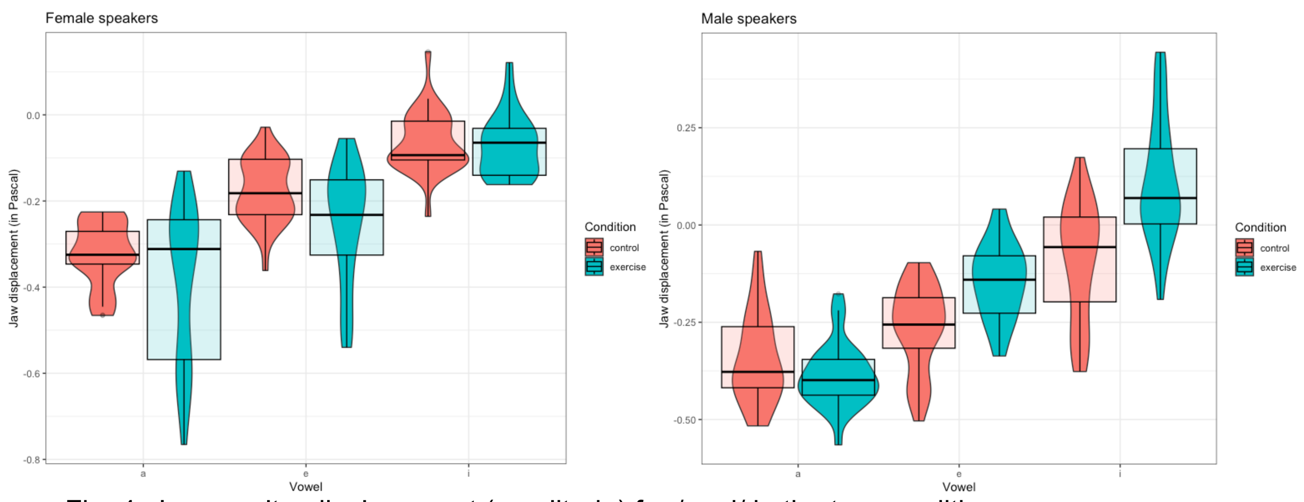

Fig. 4. Jaw results: displacement (amplitude) for /a e i/ in the two conditions

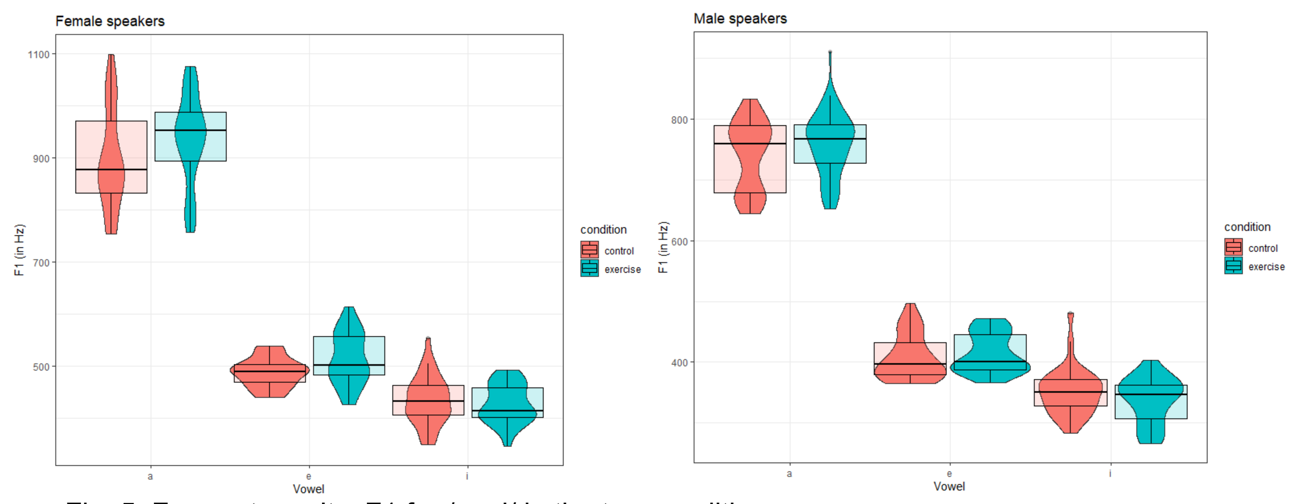

Fig. 5. Formant results: F1 for /a e i/ in the two conditions

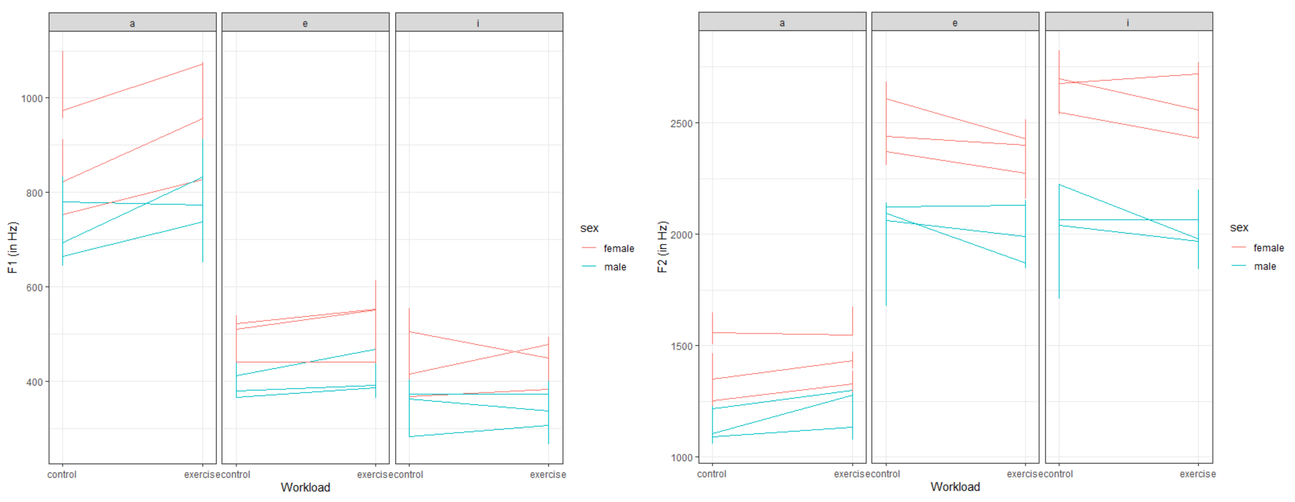

Fig. 6. Formant results by speakers: F1 (*left*) and F2 (*right*) for /a e i/ in the two conditions.

Observations:

- speaker variation observed (Fig. 6) but difficult to interpret due to small sample size (i.e., pilot study);
- t-tests showed only significant differences between conditions in females /e/ (F1 and jaw), males /i/ (F2 and jaw), and males /a e/ (jaw)

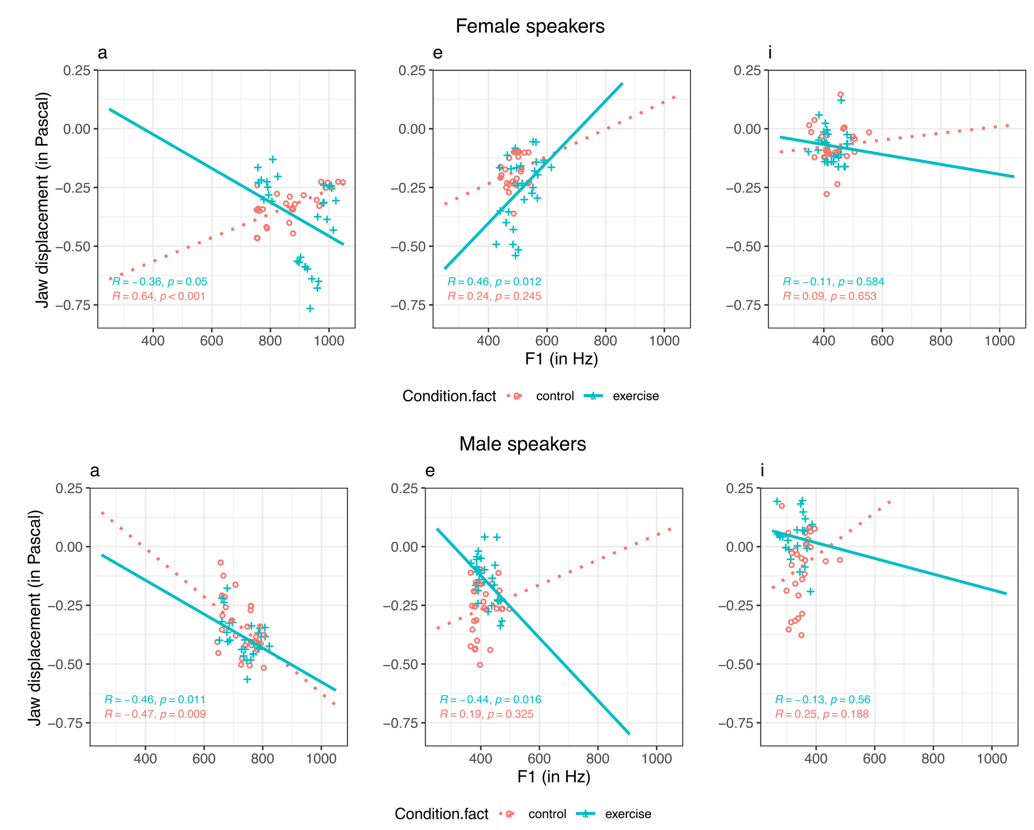

Fig 7. Jaw displacement and F1 correlations for /a e i/ in the two conditions.

Conclusions and outlook

Physical activity affects vowel production:

- In closed vowels → higher jaw; lower F2; no correlation jaw/F1.
- In open vowels → lower jaw, higher F1 and F2; stronger jaw/F1 correlation.

Future work: more data (more **speakers**, more **languages**); correlation with **prominence** (more jaw displacement [15]); correlation with **phrase-internal pauses** (more phrases → more jaw displacement)

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