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Somatosensory-based tongue response to tongue stretch perturbation during steady state vowel production: EMG data and biomechanical modeling

Pascal Perrier, Morgane Bourhis, Maxime Calka, Mohammad Ali Nazari, Yohan Payan & Takayuki Ito

Univ. Grenoble Alpes, CNRS, Grenoble INP, GIPSA-lab & TIMC



Introduction

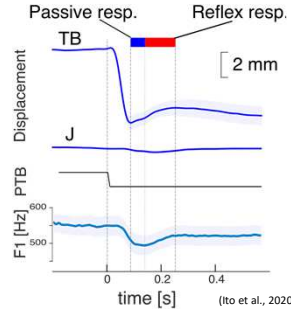
Tongue posture can be controlled using on-line sensory feedback for the stabilization of produced speech sounds. Although reflex mechanisms such as stretch reflex have been known to be involved in neural feedback control for the limb system, previous studies have been failed to provide evidence for any short-latency reflex in the human tongue (Bratzlavsky and van der Ecken 1974, Neilson et al., 1979).

In our behavioral study using tongue-stretch perturbation, a relatively quick compensatory response (< 130 ms) was found for tongue posture stabilization in vowel production, which might be driven by short-latency reflex mechanisms (Ito et al. 2020).

To further investigate this idea, this study aims to show **neurophysiological evidence for reflex in the tongue during vowel production by the recording of tongue muscle activity.**

We examined:

- whether the tongue EMG showed an increase with short latency in response to the tongue perturbation during speech production.
- whether the observed response is due to an artifact by comparing with the resting task.
- whether the observed response can be voluntarily modulated.
- whether the observed response can be task-specific.



Method

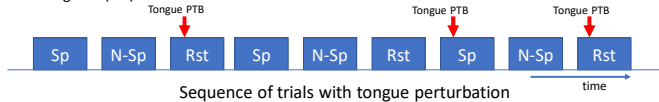
Participants:

- Eight native French speakers.

Experimental procedure:

Session 1: Speech, Non-speech and Resting tasks

- Participants were asked to carry out one of the following tasks in order
 - Speech task (Sp): Sustain the vowel /i/
 - Non-speech task (N-Sp): Produce the muscle activation of the tongue at the same level of the one in the speech task by monitoring filtered muscle activation
 - Resting task (Rst)

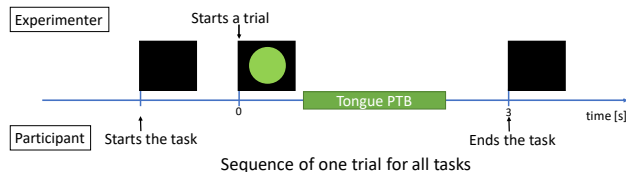


Session 2: Voluntarily reaction task (VR)

- Produce the vowel /i/ as in the speech task
- Produce a maximum muscle contraction when the perturbation was perceived

Session 3: Vowel production task (No tongue perturbation)

- Sustain the vowels /i/, /e/, /ɛ/, /a/ and /u/ in pseudo-randomized order
- Recorded five productions in each vowel

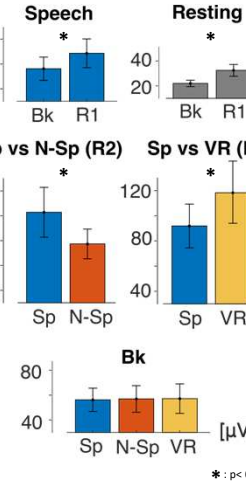
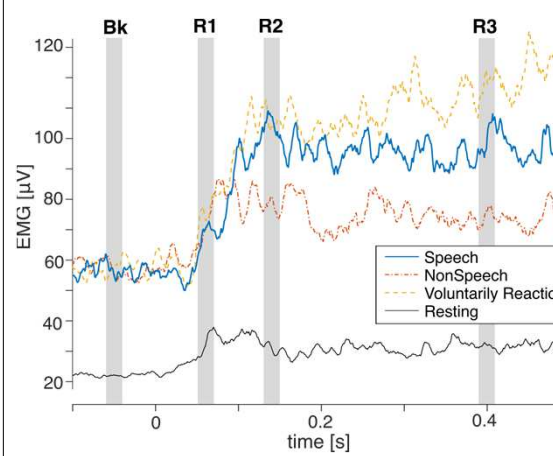


Data analysis:

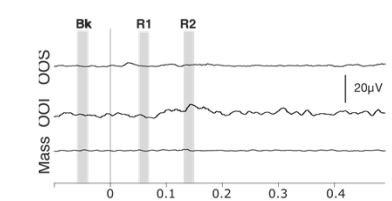
- EMG data was filtered by 30-2000 Hz band-pass filter, rectified and smoothed.
- All data was aligned at the perturbation onset.
- Amplitude was calculated using 10 ms temporal window (Bk, R1, R2 and R3).

Results

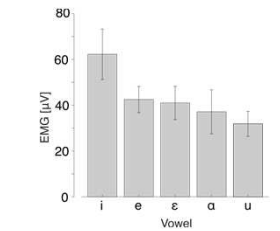
Reflex responses in response to the tongue perturbation



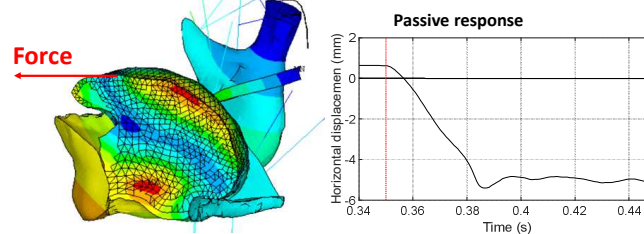
EMG responses in the other muscles



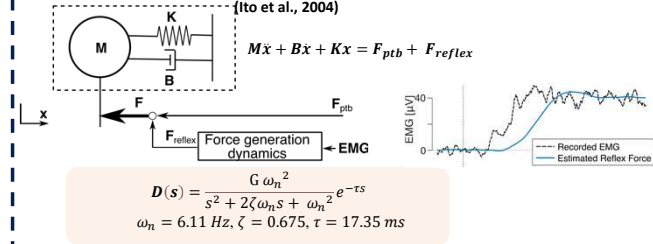
EMG in the vowel production task



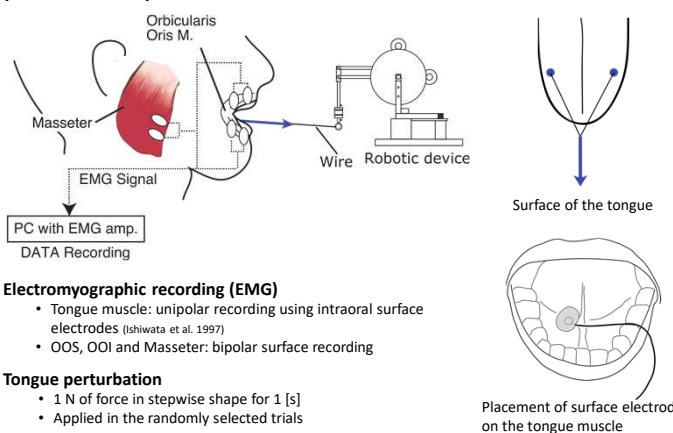
Simulations: 3D tongue model (Calka et al., 2023)



Simplified tongue model (Ito et al., 2004)



Experimental setup:



Electromyographic recording (EMG)

- Tongue muscle: unipolar recording using intraoral surface electrodes (Ishiwata et al. 1997)
- OOS, OOI and Masseter: bipolar surface recording

Tongue perturbation

- 1 N of force in stepwise shape for 1 s
- Applied in the randomly selected trials

Summary

- A reflex response was clearly induced in response to the tongue perturbation.
- The response latency in the resting task was similar to that of the main reflex response, suggesting no evidence of a short-latency reflex associated with mono-synaptic reflex.
- The peak response in the non-speech task was smaller than in the speech task, suggesting that the reflex gain was specifically modulated for speech task.
- Using the recorded EMG response, the observed displacement change was successfully reproduced through mathematical simulation.

Reflex mechanism contributes to the compensatory mechanism of the tongue posture stabilization for speech production.

Acknowledgement

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References

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