F1 and F2 measurements for French oral vowel with a new pneumotachograph mask

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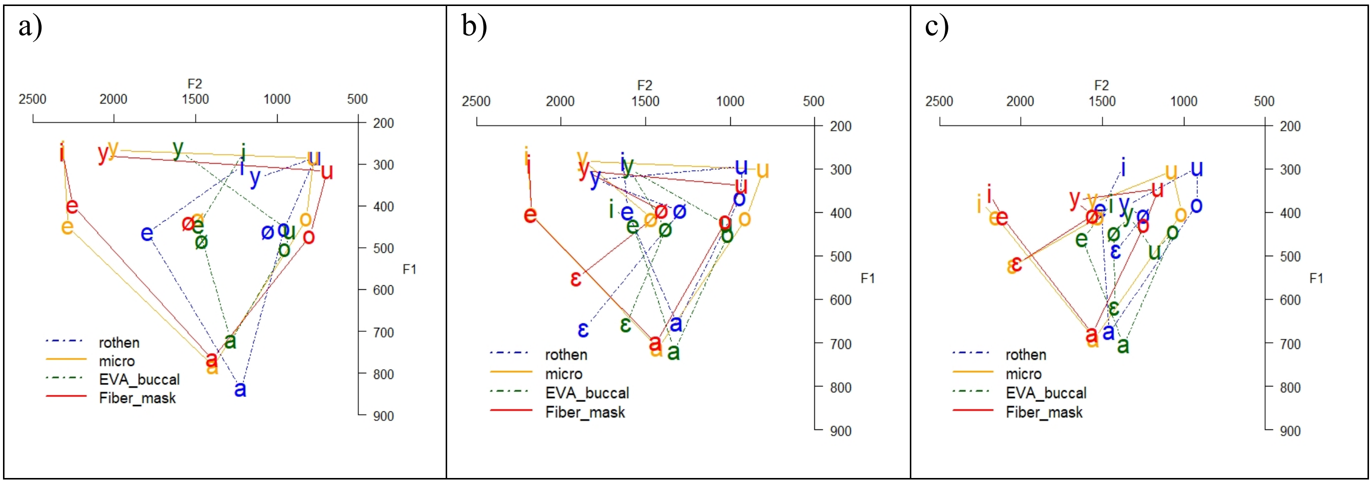
Introduction: In experimental phonetics, it's difficult to record different parameters on the same time. Indeed, combining acoustic and aerodynamic acquisitions is particularly challenging. In 1977, Rothenberg showed with a circumferentially vented pneumotachograph mask, that the vented mask had relatively low acoustic impedance. Several devices available to record aerodynamic data use different masks but it seems each time acoustic disturbance occurs; for instance, the rigid EVA™ mask (Teston & Galindo, 1995) acts as a low-pass filter which creates a strong resonance towards 1.4 kHz, an anti-resonance phenomenon at 3.5 kHz (Ghio & Teston, 2002) or a spectral attenuation in frequencies above 2 kHz. A pneumotachograph developed at Laboratoire de Phonétique et Phonologie (LPP) uses a mask made of synthetic fibers, instead of conventional rigid materials. This mask is acoustically almost transparent, and thus the radiated speech sound through the mask is almost free from acoustic distortions. The mask supplies a small resistance, as is necessary to measure airflow without perturbing much sound propagation (Honda & Maeda, 2008; Vaissière & *al.*, 2010).

Objectives: The goal of the current study is to validate that the acoustics of the fiber masks get closer to the acoustics of recording without a mask, that is to say without distortions.

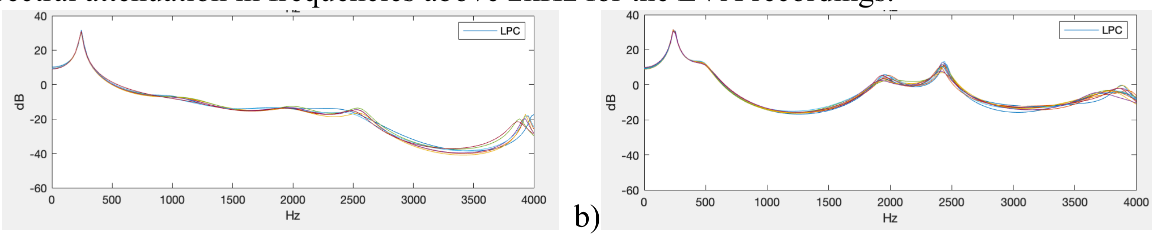
Method: Our corpus is composed of 3 parts: oral vowels in logatoms (n=872) "il a dit V: comme dans pV, pVp, pVp pVp tu n'as pas dit pVpVpVp mais pVpVpVp" with V= /i e ɛ a o u y ø/ and the first vowel (V:) as a sustained vowels (n=112) and the same vowels in the context of sentences in different position. For example: "Popo a posé le pot sur sa peau" (n= 877). Two female French native speakers repeat the corpus two times for each recording. Recordings took place in the soundproof chamber of the LPP. We did four types of recordings: 1) Acoustic-only microphone linked to a soundcard Protools, 2) Aerodynamic data recorded with the rigid EVA2™ mask with oral mask and the microphone linked to an acquisition card (DT9003), these two first recordings were made with the microphone AKG C520L, 3) One recording with the fiber mask and 4) Last recording with the Rothenberg mask, these two recordings were made with the microphone Primo EMU-4520 linked to an acquisition card (DT9003). All data are resampling to 20000 Hz. For each recording, we extract F1 and F2 for all vowels: values were taken at the middle of the vowel.

Results: Statistical software R was used for Anova analysis; a value of $p<0.05$ was considered significant. We observed thanks to the vowel triangle a strong similarity between the formant structure of the fiber mask (Fiber_mask) and of our acoustic recording (micro) for every type of vowels. Indeed, we found no significant differences for the F2 for each sustained vowel. For the logatoms, we found significant differences for [o] ($p<0,00001$) and for the sentences ($p<0,01$). Regarding F1, we found significant differences for the sustained vowel [e] ($p<0,01$) between the fiber mask and the micro. Records with EVA2™ (EVA_buccal) show a really distinct structure and a highly deformed triangle. Our results show a strong modification of F2 for the EVA recordings. F2 is probably influenced by the resonance at 1400 Hz (Ghio & Teston, 2002) and the anterior vowels are more influenced by the resonance. We found significant differences for F2 and the sustained vowels [i] ($p< 0.00003$) and [e] ($p<0,05$) between EVA and fiber mask recording. The significant differences between the EVA and the fiber mask recordings remain for the logatoms and sentences context for F2. We can observe that the vowel triangle of sentences is clearly different than the vowel triangles of the sustained vowels and logatoms. Certainly, speech is more natural in the context of sentences consequently the triangle will be less wide than sustained vowels and logatoms (Lindblom, 1963). F0 values remain constant between the 4 recordings for each speaker.



<u>Figure 1</u>: Vowel triangle on the F1-F2 space. F1 and F2 average over two female speakers are indicated for four recording conditions: with the Rothenberg mask (in blue dash-dot line), microphone without a mask (in orange), with rigid EVA mask (in green dash-dot line) and with the fiber mask (in red). Sustained vowels, vowels in logatoms and in sentences are shown respectively in a), b) and c).

We found significative differences between the Rothenberg mask (rothen) and our fiber mask: for the F2 in the sentence context for [i] ($p<0e+00$), [y] ($p<0,05$), [e] ($p<0e+00$), [o] ($p<0,0001$) and [ø] ($p<0,001$), for the sustained vowels [i] ($p<0.00004$), [y] ($p<0.01$) and [ø] ($p<0,03$) and the logatoms [i] ($p<0, 00003$] [e] ($p<0,000001$) and [o] ($p<0, 003$).
A spectral analysis was done on the sustained vowel [y] from the EVA and fiber mask recording. We can see a spectral attenuation in frequencies above 2kHz for the EVA recordings.

a)  b)

<u>Figure 2:</u> LPC spectrum from the EVA in a) and the fiber mask in b) recordings

Conclusion: The fiber mask is a credible device to preserve acoustics. Other futures studies should compare the fricative acoustics and aerodynamics.

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