Somatosensory information affects word segmentation and perception of lexical information

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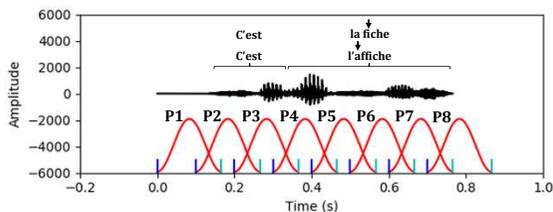
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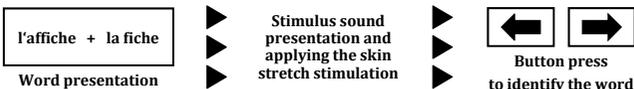
Introduction

- In human speech communication, speech signals can be perceived as the results of an integration of various sensory information.
- In case of audio-visual speech perception, integration is not limited to the perception of speech sounds [1], but extends to lexical processing [2].
- Apart from those findings, a role of somatosensory inputs has also been demonstrated in the perception of vowel and consonant sounds [3,4].
- By further extending the previous findings, the current study hypothesized that somatosensory inputs associated with facial skin deformation should also change the perception of lexical information and that the effect could depend on the timing between somatosensory and auditory inputs.
- We applied somatosensory perturbation at different timings along the presentation of auditory stimulation during a perception task involving French nouns with elisions.
- Lexical contrast in French nouns with elisions.
  - e.g., "l'affiche" ["the poster" in English] - "la fiche" ["the form" in English].
  - The meaning of two words ("l'affiche" and "la fiche") are different, but the pronunciation is the same: /lafiʃ/

Methods

- 4 native French speakers participated in an identification task with pairs of French words with elisions leading to the same pronunciation.
- 17 pairs of French words with elisions were used as stimuli.
- The words were embedded in a carrier phrase, "C'est ____ [This is ____]". The stimulus sentences were pronounced naturally (without hyper-articulation) by a native male French speaker, and recorded at 44.1kHz.
- Stimulation.
  - Skin of the face or forearm was stretched using a sinusoidal pattern at 6 Hz produced by a robotic device (Phantom 1.0, SenSable Technologies).
  - 8 timings of stimulus onset (P1 - P8) were tested. The onset of P5 was set at the peak of the first target vowel. Onsets were separated by 0.1 s.
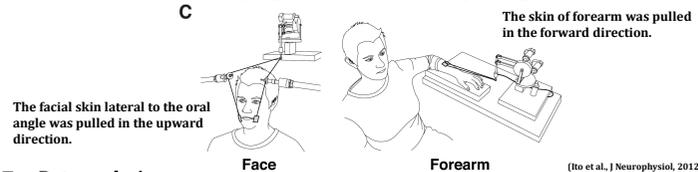

- Sequence of a single trial.

- The total number of trials was 544 (17 pairs * 8 timings * 4 repetitions).
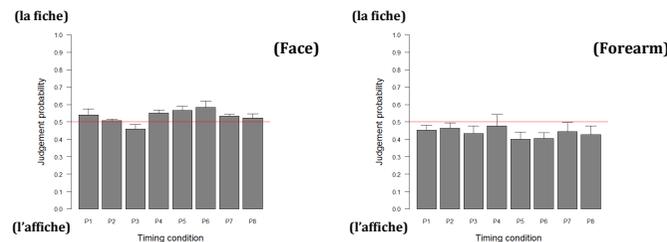
Methods

- Experimental condition.
  - We tested the two stimulation sites (Face and Forearm, one per group), as done in [5], to examine whether the perceptual change can be found only between the sensory inputs associated with speaking (Face).

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The skin of forearm was pulled in the forward direction.

The facial skin lateral to the oral angle was pulled in the upward direction.

Face   Forearm   (Ito et al., J Neurophysiol, 2012)

- Data analysis.
  - Judgement probability: Percentage of the subject's response corresponding to "la ____" (e.g., "la fiche" responses).
  - Reaction time: Delay between the onset of stimulus sound presentation and the timing of the key press.
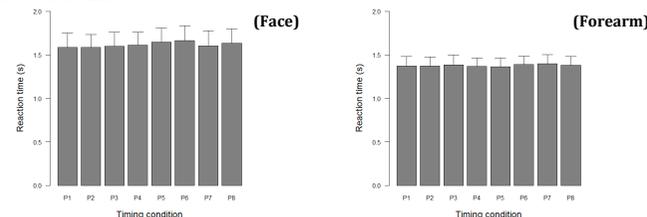
Results

- Judgement probability

- In the Face condition, the judgement probability was modulated according to the timing of somatosensory onset [$F(7,21) = 3.73, p < 0.01$]. The smallest judgement probability was found at P3 and the largest at P6. Post-hoc tests with Bonferroni-correction showed no significant differences between combination ($p > 0.09$ for all tests).
- There was no reliable difference in the Forearm condition [$F(7,21) = 0.89, p > 0.5$].

- Reaction time

- There were no effect of timing of somatosensory onset [$F(7,21) = 1.87, p > 0.1$ in the Face condition, $F(7,21) = 1.20, p > 0.3$ in the Forearm condition].

Discussion

- The effect of the skin stretch stimulation on lexical perception was found in the Face condition, but not in the Forearm condition.
  - The integration between articulatory movement information arising from orofacial skin stretch and speech sound processing seems to intervene in the perception of current French lexical perception.

- The judgement probabilities were altered according to the onset timing of facial skin stretch.
  - Speech articulatory movement often proceeds the production of speech sound. This may be reflected in the current results in which the largest effect was found when the somatosensory stimulation was applied earlier than the timing of the first vowel in the lexical utterances (e.g., "a" in "affiche" with P3 and "i" in "fiche" with P6).
  - Visually-presented information concerning articulation can give a clue for word segmentation in current French lexical perception [2]. This seems to be consistent with our results. Applying facial skin stretch stimulation at a suitable timing may provide information concerning articulation relevant for lexical processing.

Summary

- The perception of French words with elisions was altered by somatosensory information when it was applied on the face at the timings.
- This result suggests that facial skin deformation related to speech motion also affects higher-level language processes (word segmentation/perception of lexical information).

References

[1] McGurk and MacDonald, "Hearing lips and seeing voices," *Nature*, 264, pp. 746-748, 1976.
[2] Strauss et al., "Visual lip information supports auditory word segmentation," *FAAVSP2015*, 2015.
[3] Ito et al., "Somatosensory function in speech perception," *Proc. Natl Acad. Sci. USA.*, 106, pp. 1245-1248, 2009.
[4] Gick and Derrick, "Aero-tactile integration in speech perception," *Nature*, 462, pp. 502-504, 2009.
[5] Ito and Ostry, "Speech sounds alter facial skin sensation," *J Neurophysiol*, 107, pp. 442-447, 2012.

Acknowledgments