Sensorimotor Learning and Transfer During English and French Sentence Production in Bilinguals

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Introduction
Auditory-motor adaptation in speech is typically studied by altering the sound of the voice as vowel sounds are produced in simple contexts. After a period of baseline production with normal auditory feedback, the formant structure of the vowel sound is altered using a real-time signal processor so that participants hear a different vowel from the one they intended to produce. Over hundreds of trials adaptation is observed; participants alter their formant productions to offset the induced error in their speech acoustic signal (Houde and Jordan, 1998; Purcell and Munhall, 2006).

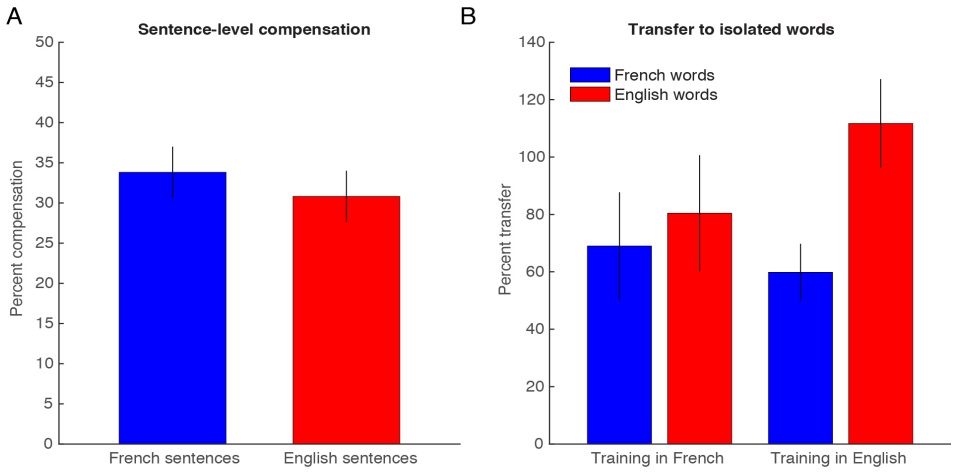
We recently demonstrated that sensorimotor adaptation can be observed during complex, sentence-level speech (Lametti et al., 2018). Participants in the study produced fifty different sentences that varied in length and syntactic structure, during which the formant structure of *all* vowel sounds was altered and played back to them in real-time. Robust feedforward compensation in sentence production was observed that precisely matched the formant perturbation directionally in F1/F2 acoustic space, offsetting about 35% of the induced acoustical error. Furthermore, the compensatory changes transferred to the production of isolated words containing a range of individual vowel sounds. The results demonstrated that speakers actively monitor and adapt the acoustics of highly complex speech in a vowel-specific manner.

Here we present pilot work in which we use the rich linguistic environment afforded by sentence production to examine the relationship between language and sensorimotor control in speech. In a group of L1 French / L2 English bilinguals, we test whether sensorimotor adaptation acquired during French sentence production will be applied to vowel production in English, and vice versa.

Methods
We translated 250 of the Harvard Sentences (a corpus of phonetically balanced English sentences) into French. From among these, fifty English-French sentence pairs were selected for which the translations were the best match on word/morpheme count and acoustic properties. The study design paralleled Lametti et al. (2018). In brief, participants read sentences into a microphone as they appeared on a computer screen and heard themselves in real-time through headphones. After a period of baseline sentence production, the first and second formant frequency of all produced vowels was altered by -49.5 mel and +49.5 mel (respectively) to induce sensorimotor adaptation. Before and after sentence adaptation, a transfer test involving isolated words assessed formant production in the complete absence of auditory feedback (noise masking). The transfer test consisted of randomized productions of eight English words and eight French words with vowel sounds that were comparable across languages (e.g., "pat" and « pâte »).

Twenty adult participants were tested (10 male, 10 female), all of whom were L1 speakers of Quebec French and moderate/high proficiency speakers of English (as reported using an adapted version of the Language Experience and Proficiency Questionnaire; LEAP-Q). Subjects were tested in two sessions, one week apart. In one session, they experienced sensorimotor adaptation during English sentence production, and the extent of transfer to both English and French words was assessed; in the second session, they experienced sensorimotor adaptation during French sentence

production, and the extent of transfer to English and French words was assessed. Session language order was balanced among the 20 subjects. Following Lametti et al. (2018), speech compensation was indexed by the degree to which changes in formant production oppose the -F1 / +F2 auditory feedback perturbation.



Results

Figure 1A shows the percentage of formant compensation in response to altered auditory feedback during the production of French (blue) and English (red) sentences. Participants were found to offset 30-35% of the induced acoustical error in both languages. Figure 1B shows the degree of transfer of this compensation to the production of isolated English and French words, shown as a percentage of the sentence compensation magnitude. Compensatory speech patterns learned in the context of French sentence production were readily applied to the production of both French and English words (left bars). Compensation acquired during English sentence production similarly showed robust transfer to word production in both English and French words (right bars). These early results suggest that, in speakers of more than one language, newly acquired sensorimotor transformations in speech may not be language specific, but rather are applied to vowels across language contexts.

References

Houde, Jordan (1998) Sensorimotor adaptation in speech production. Science 279:1213–1216.

Lametti DR, Smith HJ, Watkins KE, Shiller DM (2018) Robust Sensorimotor Learning During Variable Sentence Level Speech. Curr Biol. 28 (19), 3106-3113

Purcell DW, Munhall KG (2006) Adaptive control of vowel formant frequency: evidence from real-time formant manipulation. J Acoust Soc Am 120:966–977.