Neural correlates of subsyllabic speech motor sequence learning

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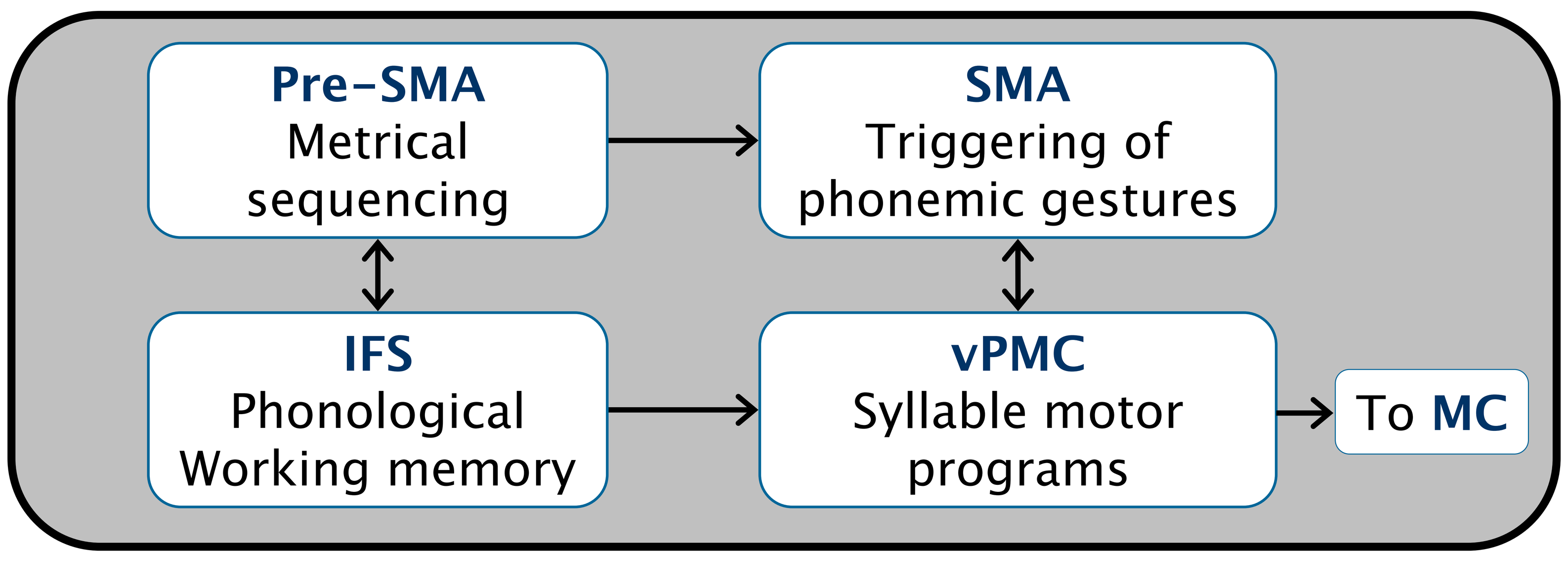
Background

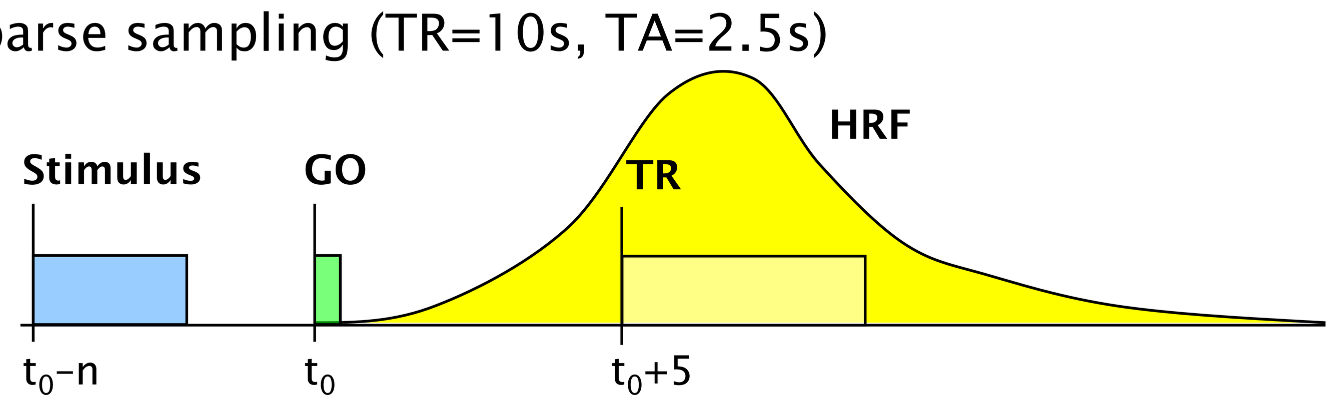
- A large body of literature is devoted to motor sequence learning with tasks using the fingers, hand, arm, or eyes.
- However, not much is known about speech motor sequence learning, especially its neural correlates with overt production.
- Based on motor sequence learning literature and speech sequencing literature, we propose that this network is necessary to speech motor sequence learning:



- We hypothesize that with learning a sequence is "chunked" into larger, and therefore fewer, motor chunks. Thus, the load on the pre-supplementary motor area (**pre-SMA**) and inferior frontal sulcus (**IFS**) will be reduced with learning.

Methods

- *Subjects*: 12 monolingual American English speaking subjects
- *Stimuli*
  - 15 **overlearned** subsyllabic sequences with legal consonant clusters in English
    - e.g. BLERK
    - 60 repetitions of each sequence over 2 days of practice
  - 15 **learned** subsyllabic sequences with illegal consonant clusters in English
    - e.g. FSEFK
    - 60 repetitions of each sequence over 2 days of practice
  - 15 **novel** subsyllabic sequences with illegal consonant clusters in English
    - e.g. TFISCH
    - Novel at time of fMRI scan
- *Paradigm*:
  1. Auditory & orthographic sequence cues (1.5 & 0.5s)
  2. Jittered pause (0.5-1.5s)
  3. GO signal, tone
  4. Subject produces sequence
- *fMRI acquisition*
  - Siemens Trio Tim 3T, 32 channel head coil
  - Sparse sampling (TR=10s, TA=2.5s)



  - Voxel size: 3.1x3.1x3.0mm
- *fMRI analysis*
  - **Nipype** (http://nipy.sourceforge.net/nipype) provides an open-source interface between neuroimaging software tools.
  - Functional volumes realigned to subject's anatomical volume and first level model estimated with **SPM8**.
    - HRF modeled as finite impulse response
    - Utterance duration as regressor in model
  - Contrasts projected to an average reconstructed cortical surface (based on registrations to a subject's own surface) and smoothed (FWHM = 6mm) using **Freesurfer**.
  - One sample t-test thresholded at $p < 0.001$ for voxels with cluster-wise threshold of CWP < 0.05 (estimated using a Monte Carlo simulation) with **Freesurfer**.

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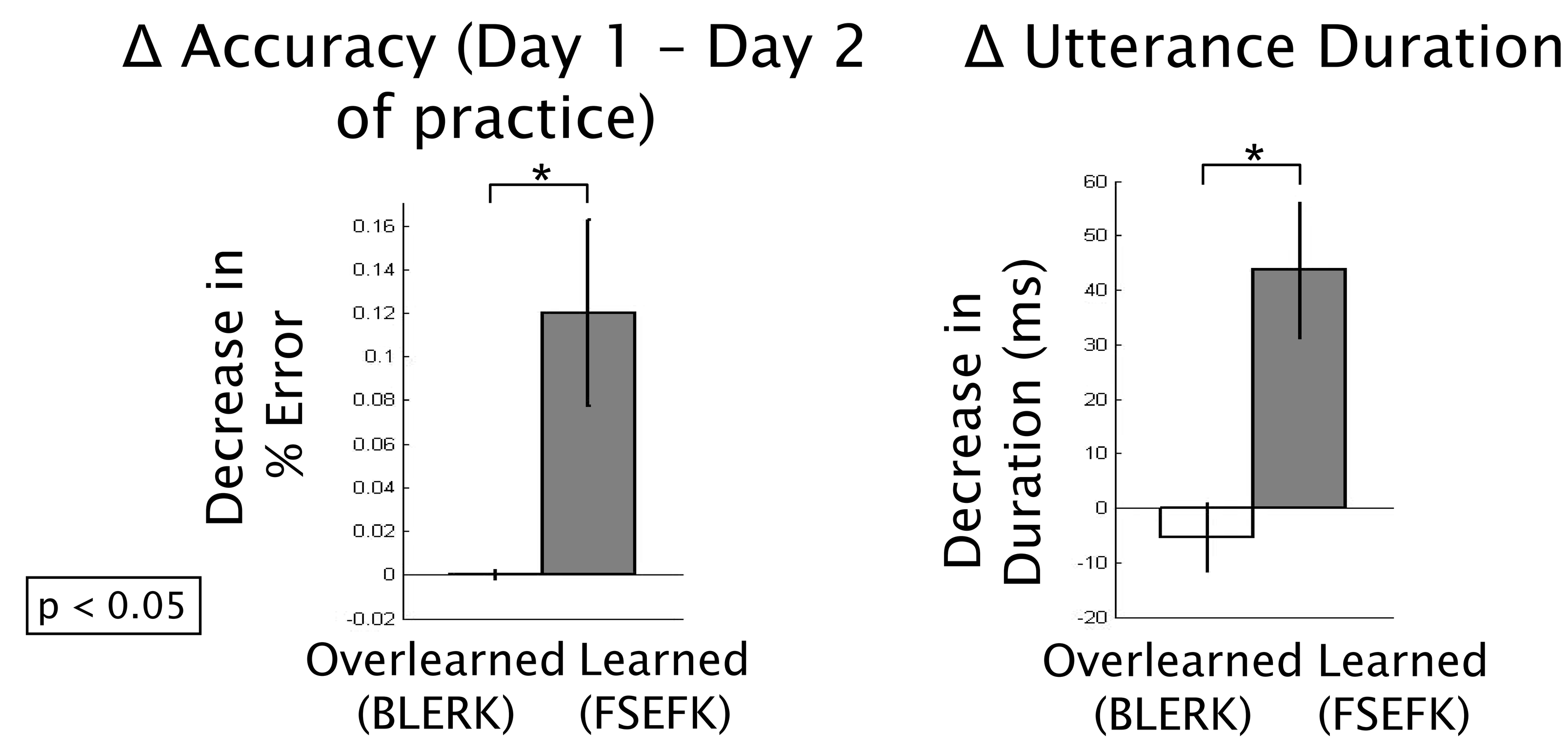
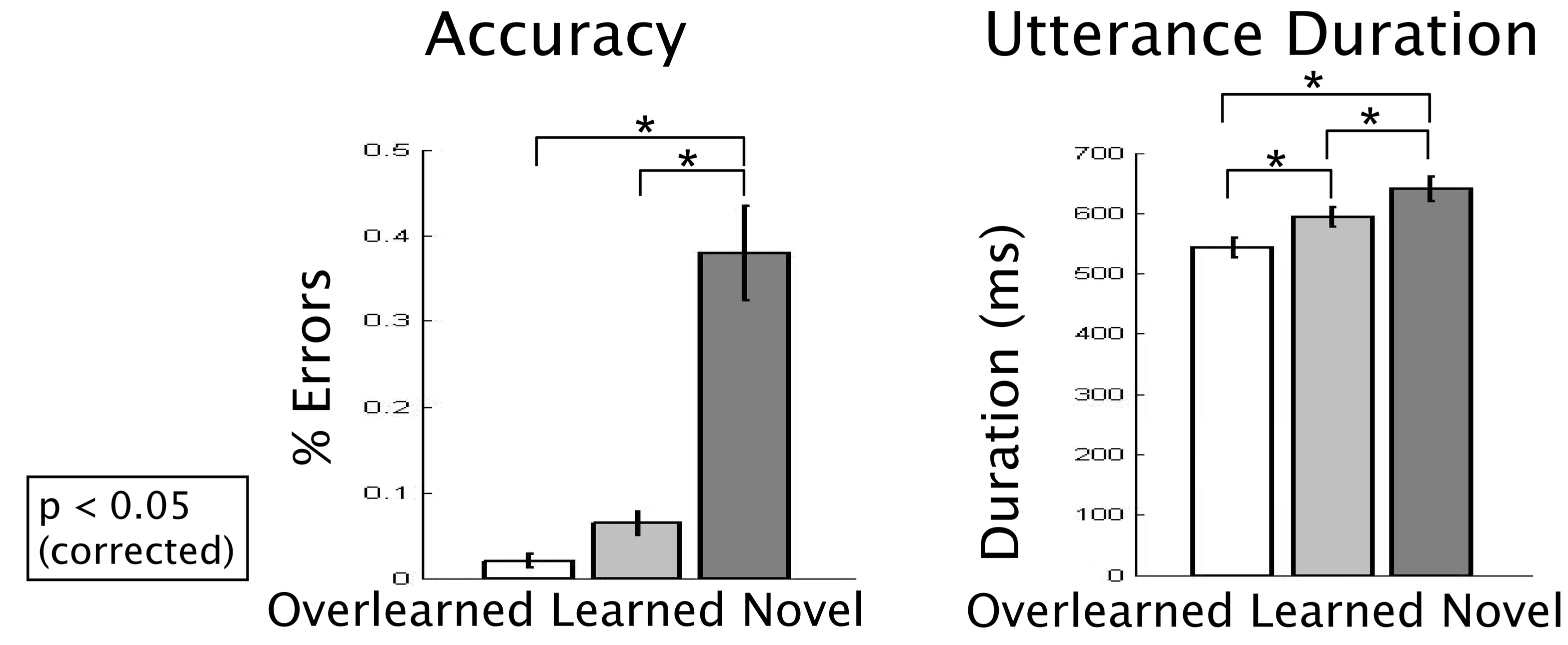
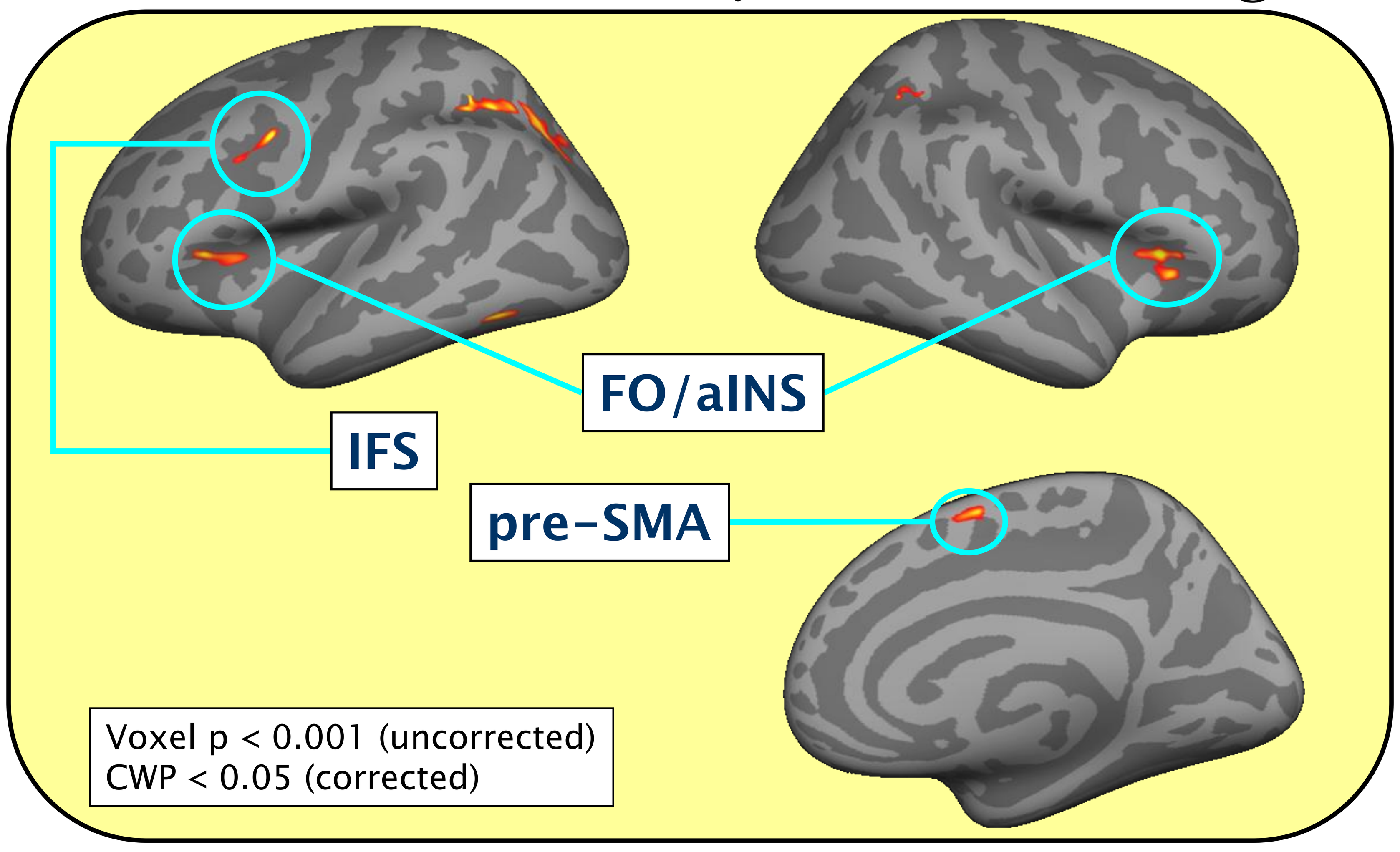
Changes with practice for learned but not overlearned sequences



Learning specific to practiced subsyllabic sequences



Decreases in activity with learning



Discussion

- We demonstrated that subsyllabic speech motor sequence learning can occur with only 2 days of practice.
- We correctly predicted that learning of subsyllabic sequences would result in decreased activity in the **IFS** and **pre-SMA**.
- We suggest that with learning the subsyllabic sequence is produced with larger (and thus fewer) motor chunks. This reduces the parallel loads on the
  - **phonological working memory** in the **IFS** and
  - **metrical sequencing processes** in the **pre-SMA**.
- Learning also resulted in a decrease in fMRI activity in the frontal operculum/anterior insula (**FO/aINS**)
- Based on studies of learning to produce non-native phonemes and learning of non-native phonological contrasts in which learning also results in an fMRI activity decrease in this region, we suggest that this change in activity results from the
  - **formation of new subsyllabic phonological representations** in the **FO/aINS**

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