Neural correlates of subsyllabic speech motor sequence learning

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:

![Diagram of neural correlates of subsyllabic 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 SPMB.
  - 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.

![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.

![Changes with practice for learned but not overlearned sequences]

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