Simultaneous monitoring of tongue tip movements in functional MRI motor tasks for speech and swallowing studies

B. P. Sutton[1,2], C. A. Conway[1], and D. P. Kuehn[3]

[1]Bioengineering Department, University of Illinois at Urbana-Champaign, Urbana, IL, United States, [2]Beckman Institute, University of Illinois at Urbana-Champaign, Urbana, IL, United States, [3]Speech and Hearing Science, University of Illinois at Urbana-Champaign, Champaign, IL, United States

Introduction Cortical control of coordinated muscle activities for speech and swallowing are critical for self-sustaining life functions. However, this neuromuscular control can be impacted by stroke and other neuromuscular disorders such as ALS and MS. Functional MRI studies of motor control for speech [1] and swallowing tasks [2,3] have been performed, some with devices to monitor muscle activity during the fMRI acquisition. Structural movement is monitored with a respiratory belt around the neck to monitor swallows [4] or with an air bulb to monitor tongue tapping [5]. Although these devices are MR compatible, they can interfere with normal muscle function and would not support multi-dimensional measurements of complex motions such as in the tongue.

In this work, we develop a pulse sequence that interleaves image-based monitoring of the structural movements with a functional MRI (fMRI) acquisition to assess neuronal control. This method enables the monitoring of complex structural motions, inherently synchronized with simultaneous fMRI acquisition and without the need for additional hardware. Additionally, subjects can perform uncued tasks.

Methods Data were acquired on a healthy young adult male subject in accordance with the institutional review board on a Siemens 3 T Allegra MRI scanner. A 6-shot spiral FLASH acquisition was used for the midsagittal slice to visualize tongue tip motion (8 mm thick, 128 matrix size, 1.88 mm in-plane resolution, TE 0.9 ms, TR per shot 6.6 ms) [6]. Interleaved with the dynamic scans, functional slices were acquired with single-shot spiral-in acquisition angled through visual and primary motor areas (4 mm thick, 64 matrix size, TE 25 ms, TR 26 ms). The midsagittal slice was acquired between each of 4 functional slices. The effective TR for the functional volumes was 0.2615 s. The midsagittal dynamic image, acquired between each slice in the functional volume, was updated every 65 ms, or about 16 times per second. An example of the imaging gradient waveform is shown in Figure 1 at right.

A simple tongue-tapping task was used to demonstrate the simultaneous monitoring of tongue motion and cortical control. A cued block task (20 s on/20 s off, 5 repeats) was compared to a cued event-related task (one tap every 20 s for 200 s) and a self-paced task where the subject was not cued when to tap his tongue. The task cues were displayed as flashing checkerboards with instructions to tap when flashing for the block task and to tap when flashing started or stopped for the event-related task.

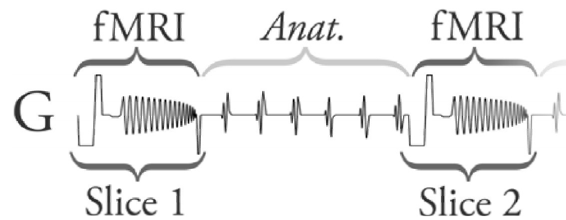

Figure 1. Representative gradient waveform showing interleaved functional and anatomical acquisitions for the first two slices in an fMRI volume. Note: Spiral designs were modified to save space for presentation.

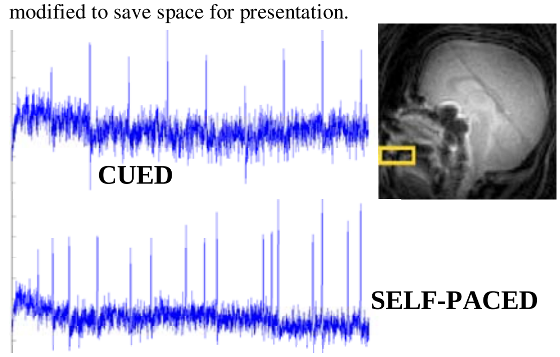

Figure 2. The average intensity over the chosen ROI plotted vs. time. Spikes in average intensity correspond with each tongue tap and provide a robust indicator of each tap event. Data shown is from cued and self-paced event-related tasks.

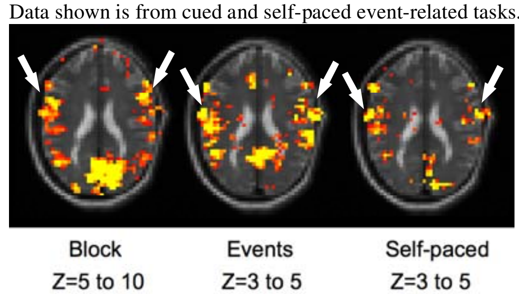

Figure 3. Z score maps from fMRI analysis. **Block** and **Events** were cued with a flashing checkerboard. **Self-paced** had no visual stimulus. **Block** activations are thresholded at z=5, whereas **Events** and **Self-paced** are thresholded at z=3 (p<~0.001). Primary motor areas are indicated by arrows.

Results The timing of each tongue tap was identified by thresholding a time series of average intensities over an ROI in the midsagittal image. The ROI was placed so that the tongue tip would enter and exit during tapping, creating a spike in average intensity that was a robust indicator of the motion. Measures from shape analysis may be required for more complex motions. The ROI-based tap indicator was verified by comparing detected tap timings to the expected timings from the cued event-related task. For the self-paced task, event timings from the ROI method were fed into FSL for analysis. Figure 2 shows a dynamic image and the ROI with the timeseries plots for cued and self-paced event-related acquisitions. Figure 3 shows the functional images for all three tasks. The block task has been thresholded at Z=5, whereas the event-related tasks have been thresholded at Z=3 (~p<0.001). The self-paced task shows reliable activation of primary motor areas (indicated by arrows), however, they are reduced in size relative to the cued event-related task.

Discussion and Conclusion The proposed sequence creates a platform for examining neural activations for motor tasks in speech and swallowing, allowing real-time monitoring of the task performance simultaneous with the fMRI acquisition. Further, the technique allows for self-paced experimental designs without the need for, or interference from, additional monitoring hardware.

References[1] Wildgruber, et al. 1996. Neuroreport 7: 2791-5. [2] Hamdy, et al. 1999. Am J Physiol 277:G219-25. [3] Mosier, et al. 1999. Am J Neuroradiol 20:1520-26. [4] Martin, et al. 2001. J Neurophysiol 85:938-50. [5]. Crow and Ship. 1996. J Gerontol A Biol Sci Med Sci. 51:M247-50. [6]. Glover. 1999. Magn Reson Med 42:412-5.