

# Age-related reorganization of the functional neuroanatomy of speech production

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## Introduction

Aging is increasingly seen as a complex interplay between **degenerative processes** such as brain atrophy and neurotransmitter changes, and **brain reorganization** compensating for functional deficits [1]. To test the hypothesis that specific brain networks reorganize in aging individuals, speech production was investigated using **event-related functional MRI** and **clustered image acquisition**.

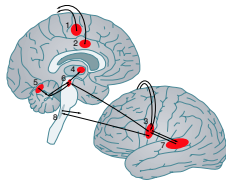


FIGURE 1: The neural network of overt speech production [2]. Supplementary motor area (1), cingulate motor areas (2), primary motor cortex (3), thalamus (4), basal ganglia (not shown), cerebellum (5), red nucleus (6), posterior superior temporal gyrus (7).

## Methods

### Participants

BOLD fMRI was acquired in 9 younger (age range = 22 - 32 years) and 9 older healthy volunteers (age range = 60 - 83 years). fMRI data of the younger participants were published separately [2].

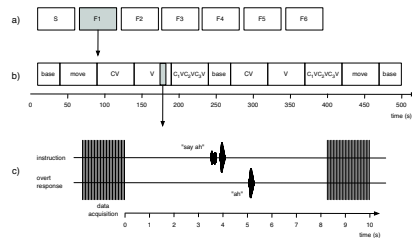


FIGURE 2: Timing diagram illustrating behavioral tasks and clustered fMRI data acquisition. a) The sequence of structural (S) and functional imaging (sessions F1-F6). b) The sequence of tasks in session F1. c) Event-related clustered fMRI acquisition. Both the auditory cue and the verbal response fall within the silent interval between multislice data acquisition. The speech waveforms represent the instruction (upper trace) and the overt response (lower trace).

### Experimental tasks

Participants were asked to repeat acoustically presented **sub-lexical speech sounds of different complexity** and to perform oral movements without vocalization. The required responses were the vowel (V) "ah", a consonant-vowel (CV) syllable (either "pa", "ka", or "ta"), a C<sub>1</sub>VC<sub>2</sub>VC<sub>3</sub> utterance ("pataka"), and **oral movements** (opening the mouth or protruding the lips). Instructions were transmitted through an fMRI compatible audio system (Avotec, Stuart, FL, USA) at a constant onset-to-onset interstimulus interval of 10 s. Six experimental sessions were performed. Each session comprised 6 separate blocks of speech, 2 blocks of oral movement (50 s each) and 3 blocks of baseline (30 s). During the baseline, no verbal instructions were given and no responses were performed (Fig. 2).

### Magnetic resonance imaging

Imaging was performed on a 3 Tesla GE MRI system with the

standard head coil. For BOLD fMRI, a **spiral-in/out pulse sequence** [3] and **clustered image acquisition** [4] were used (TR = 10 s). Based on the timecourse of the hemodynamic response function, the offset of the verbal instructions was set approximately 5 s prior to the midpoint of the data acquisition. High-resolution, T1-weighted images were acquired for structural reference.

### Behavioral measurements

**Jaw movements** were monitored using a flexible, fMRI-compatible bend sensor attached to the chin. **Vocal responses** were recorded via the microphone channel of the acoustic stimulation system.

### Data analysis

Analysis of fMRI data was carried out using the software library **FSL** [5]. Preprocessing included linear registration, brain segmentation, spatial smoothing and intensity normalization. The 6 fMRI sessions per participant were analyzed independently using general linear modeling. A mixed-effects analysis was then carried out to analyze effects across the 6 sessions of single participants. Finally, a mixed-effects analysis was performed across all participants. Statistic parametric (Z score) images were thresholded using clusters determined by  $Z > 2.3$  and a (corrected) cluster significance threshold of  $P = 0.01$ .

## Results

No significant differences in **response times** and **accuracy** were found between younger and older participants.

### Vowel vs. baseline

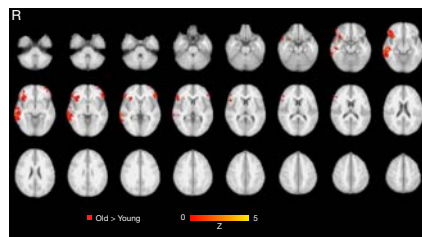


FIGURE 3: Group activation map, older vs. younger participants for the V vs. baseline condition. Stronger activation in older individuals (red) is seen in the bilateral inferior frontal gyrus and in the right middle temporal gyrus.

### Consonant-vowel vs. baseline

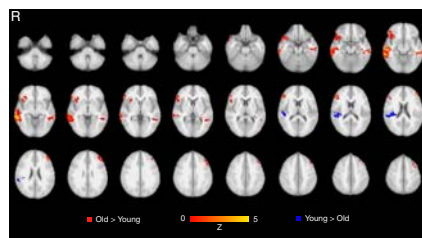


FIGURE 4: Group activation map, younger vs. older participants for the CV vs. baseline condition. Stronger activation in older individuals (red) is seen in the bilateral inferior frontal gyrus and in the right middle temporal gyrus.

### Polysyllabic utterance vs. baseline

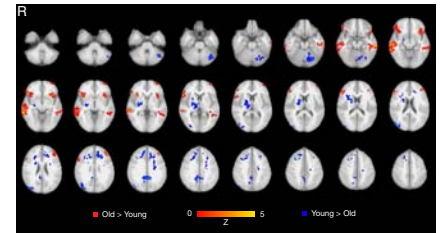


FIGURE 5: Group activation map, older vs. younger participants for the C<sub>1</sub>VC<sub>2</sub>VC<sub>3</sub> vs. baseline condition. Stronger activation in older individuals (red) is seen in the bilateral inferior frontal gyrus, the bilateral superior and middle temporal gyri and the bilateral anterior insula. Stronger activation in younger individuals (blue) is seen in the left cerebellar hemisphere, the right basal ganglia and the right thalamus.

## Discussion

The results of the present study indicate that the **neural networks** underlying speech production **reorganize** over the life span.

**Cerebellar and basal ganglia activation** were decreased in older participants. This result is in line with studies reporting a decrease in basal ganglia volume [6] and in dopaminergic neurotransmission [7] in aging. In contrast, **inferior frontal, temporal and insular activation** increased in older individuals.

These findings might suggest that impaired brain function in aging can be compensated by the recruitment of remote brain areas.

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