# Investigating the Neural Mechanisms of Speech Rate, Clarity, and Emphasis

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## Introduction

- **Speed-accuracy tradeoff**[1] — robust phenomenon observed in motor control
- In speech, **faster productions** may be achieved by
  - Increasing movement **speed**[2]
  - Reducing movement **duration** (i.e., truncating movements)[3]
  - **Restructuring motor sequences** into fewer, larger-than normal chunks[4]
- Speech motor sequencing and programming processes controlled by different **brain regions**
  - Posterior dorsal region in **left inferior frontal gyrus *pars opercularis*** associated with syllabification and order-related processing[5]
  - **Left lateral premotor cortex** associated with articulatory encoding[6]
- Neural control of speed-accuracy trade-off in speech not well characterized
- **Aim: Investigate the neural mechanisms associated with varying speech manner along a speed-accuracy continuum**

## Methods

**Participants**

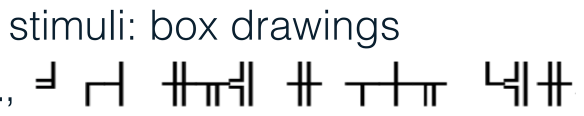
14 native speakers North American English (7F/7M; 18-35 yrs)

**Stimuli design**

24 5-syllable sentence stimuli containing 4 corner vowels: /i/, /u/, /æ/, /ɒ/

e.g., "Duke got a deep bag"

Control stimuli: box drawings

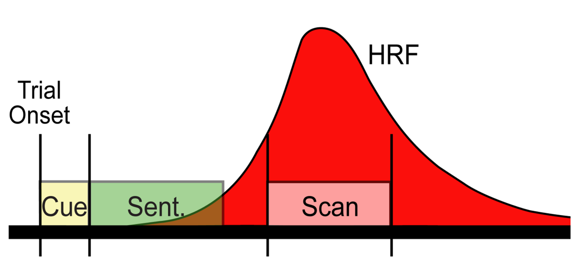
e.g., 

**Study design**

4 speech conditions: **normal, fast, stress, clear**

**Imaging**

3T Siemens Tim Trio scanner, sparse sampling protocol

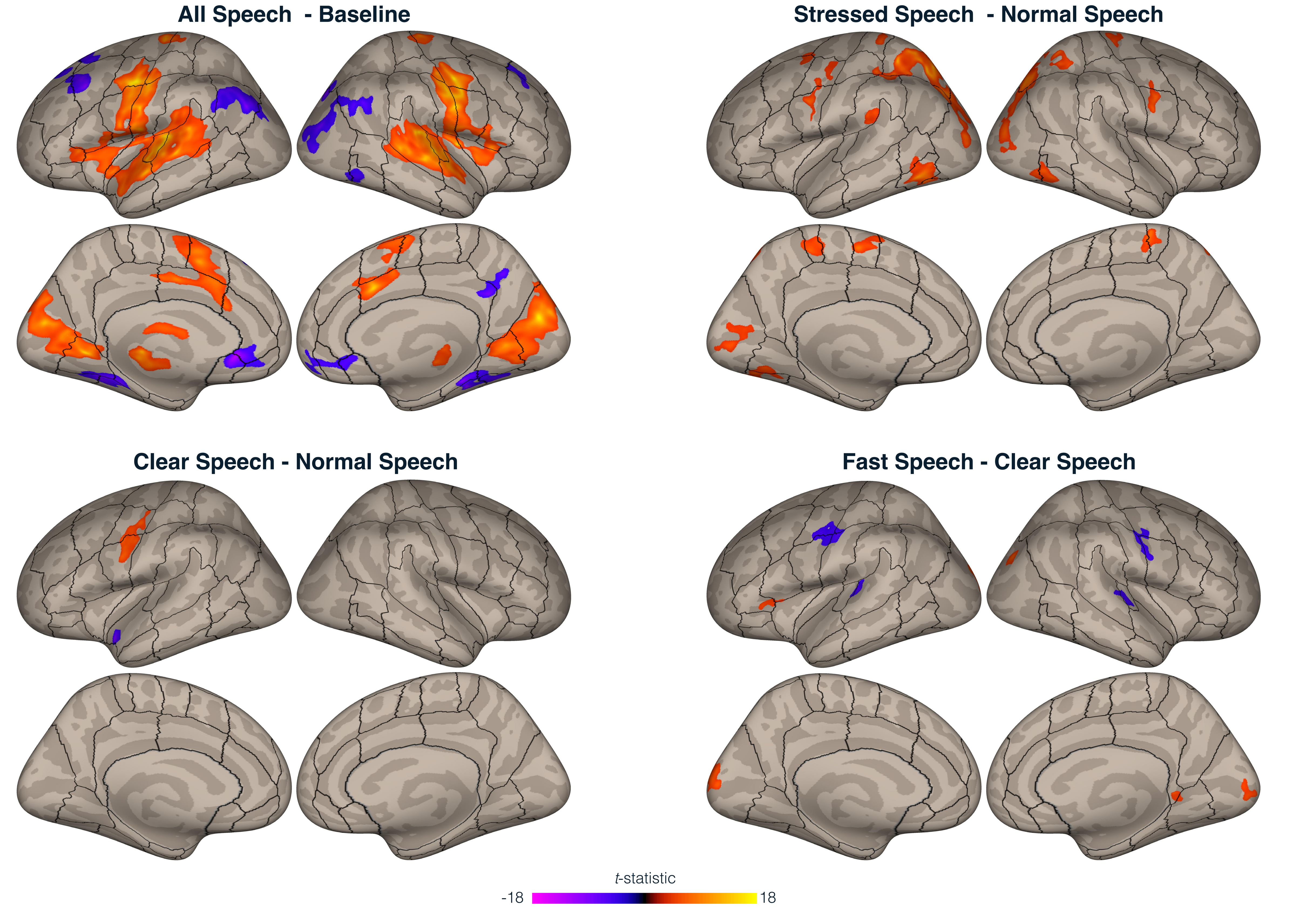



**Data analysis**

- **Audio** data segmented using *Praat*; incorrectly read trials and trials with outlying speech rates and reaction times removed
- **Functional images** realigned, unwarped, coregistered with a structural dataset, resampled to surface space (cortical) or normalized to MNI space (subcortical), and smoothed (8 mm FWHM) using *CONN* and *SPM12*
- **Surface-based cortical** and **volume-based subcortical** analyses of the following **contrasts**: (1) Speech-Baseline, (2) Fast-Normal, (3) Stress-Normal, (4) Clear-Normal, (5) Fast-Clear
- **Statistical thresholding:**
  - Suface: Vertex threshold $p < .001$, $p$-uncorrected, two-sided test; Cluster threshold $p < .05$, cluster-size $p$ FWE-corrected
  - Volume: Voxel threshold $p < .001$, $p$-uncorrected, two-sided test; Cluster threshold: $p < .05$, cluster-size $p$ FDR-corrected

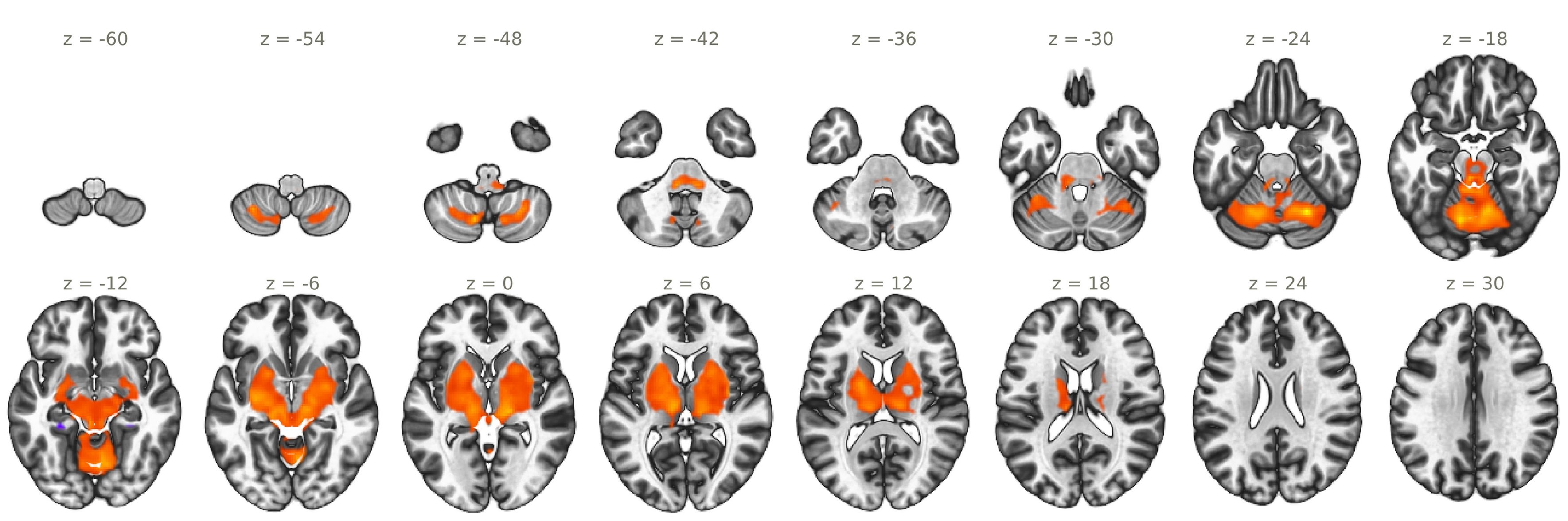
## Results

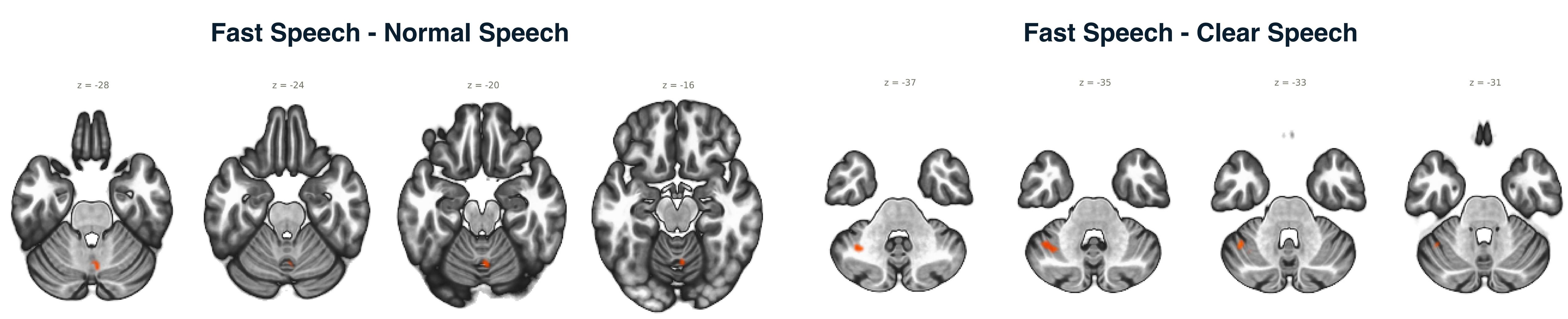
### Surface-Based Cortical Analyses




### Volume-Based Subcortical Analyses

All Speech - Baseline




## Discussion

**Compared to normal** speech production

- **Stressed** speech showed increased activation in right mid/ventral premotor cortex (PMC) and dorsal motor cortex (MC), bilateral dorsal somatosensory cortex (SC), left SMA, left posterior inferior temporal lobe, and several posterior parietal regions bilaterally
- **Clear** speech showed increased activation in left mid/dorsal MC and PMC
- **Fast** speech showed increased activation in the vermis of the cerebellum

**Compared to clear** speech production

- **Fast** speech showed decreased activation in mid/ventral MC and SC bilaterally, left planum temporale, right Heschl's gyrus, and increased activity in the left frontal operculum and the cerebellum

The findings identify **neural correlates associated with changing speech manner** and support the idea that

- **Left premotor cortex is more involved in clear speech**
- **Right premotor cortex is more involved in stressed speech**
- **Bilateral motor and somatosensory cortex are less involved and cerebellum is more involved in fast speech**

## Key References

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