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9-2016

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Neural Control of Tongue Movements Across Effort Levels

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SENSORIMOTOR INTEGRATION FOR SWALLOWING AND COMMUNICATION

Summary

Healthy adults performed speech related and non-speech-related pressure tasks at certain percentages of their maximum effort levels. Analysis of the task-related brain activation using the functional MRI revealed statistically significant scaling in the left secondary sensorimotor cortex during isometric tongue press.

Introduction

A hallmark of Parkinson's disease is a mismatch between the perceived effort and actual forces exerted during functional activities such as speech. Speech requires rapid and precise movements of key articulators such as the tongue within the oral cavity. In order to produce intelligible speech sounds, the neuromotor system must operate with enough strength so that accurate placement of the tongue occurs within the correct time frame (Robin et al., 1992).

Modulation of the forces involved in these types of tongue movements is not well understood. Previous information on neural control of force has been gained from a neuroimaging study investigating effort levels in non speech tasks such as hand movement (Spraker et al., 2007)

Methods

Participants

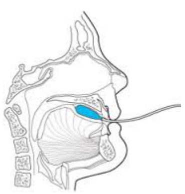
- 20 healthy adults 40-60 years of age (10 men, 10 women)

Instrumentation

- LabVIEW stimulus software provided visual cues for timing, target force levels and continuous feedback about pressures exerted
- Structural and functional magnetic resonance images (MRI) on a Siemans 3.0 Tesla Allegra MRI scanner

Procedures

- Two runs of each study task: phoneme repetition and isometric tongue press
- Participants compressed air-filled polymer bulbs in the mouth at 25%, 50%, and 75% of their individual task-specific maximum voluntary pressure



Analysis

- Processing of MRI scans via SPM tool kit within the MATLAB software
- Whole brain fMRI analysis mapped to standardized space
  - Group regions of interest (ROI) mask created by collapsing all levels of the behavior into an active vs. rest contrast (MarsBaR toolbox for SPM)
- Second level analysis
  - Apply mask from 10 randomly selected participants using a ROI analysis to evaluate how brain activity changes at different effort levels

Objectives

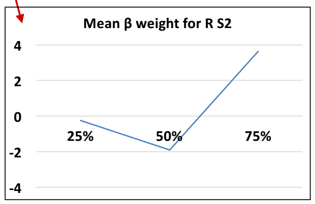
1. Identify which areas of the brain are involved in each speech related task
2. Determine which areas, if any, scale in activation according to effort level

Results

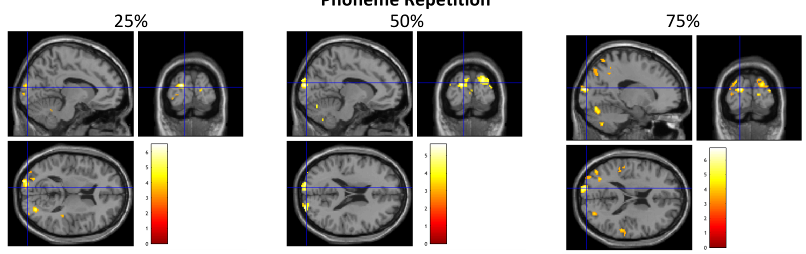
Task	Area	Cluster maxima	Scaling Level P value
Tongue	Left Supplementary Motor (L SMA)	(-24, -58, 56)	0.55
Tongue	Left Insula	(-42, -66, 2)	0.29
Tongue	Right Secondary Sensorimotor (R S2)	(18, 10, 56)	***0.015***
Tongue	Right Primary Motor (R M1)	(36, -38, 36)	0.349
Phoneme	Left Secondary Sensorimotor (L S2)	(-48, -10, 36)	0.519
Phoneme	Left Insula	(-50, -44, 10)	0.21
Phoneme	Right Secondary Sensorimotor (R S2)	(16, 6, 62)	0.683
Phoneme	Right Auditory Cortex	(52, -32, 2)	0.397
Phoneme	Right Auditory Cortex	(62, -26, -2)	0.262

Multiple areas including sensory, motor, and insular cortices were active during study tasks. The only area exhibiting statistically significant scaling was the R S2 during the isometric tongue press.

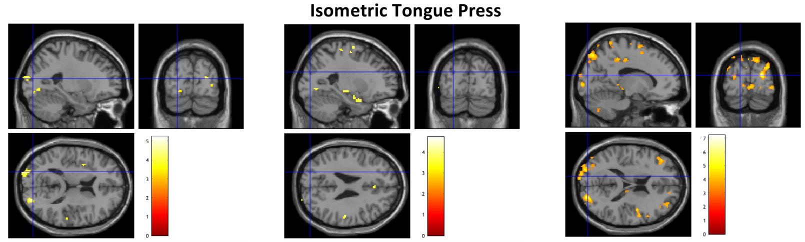
Scaling Level	Mean β weight for R S2
25%	-0.251
50%	-1.905
75%	3.64



Phoneme Repetition



Isometric Tongue Press



Discussion

Our findings showed shared activation in both sensory and motor areas deep in the brain. These areas are located deep in a sulcus directly adjacent to each other so they may be hard to distinguish. Additional activations were noted in the right insula, which is associated with motor control of speech and swallowing movements as well as self awareness (Malandraki et al., 2009).

There were multiple brain regions that exhibited activation within each individual but did not emerge as clusters of shared activation in the group ROI mask. This may reflect slight differences in the precise location of the activity across individual brains which becomes even more pronounced in older participants (Buckner et al., 2000).

Statistically significant scaling of activations was observed in R S2 which has been linked to processing of light touch, tactile attention, and somatosensory integration for voluntary skeletal movements (Eickhoff et al., 2005). The pattern of scaling suggested that the middle range of effort (50%) placed fewer sensorimotor integration demands on R S2 than either physiological extreme, consistent with findings in other studies (Solomon et al., 2000; Spraker et al., 2007). This V-shaped pattern was evident in multiple other areas but did not reach statistical significance, likely because of the wide variability across participants.

Conclusions

- Networks of activation for isometric tongue press and phoneme repetition are overlapping but different.
- Activation did scale across effort levels in some brain regions but patterns of change did not necessarily correspond directly to the effort levels.

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Acknowledgements

Analysis of these data was supported by UCARE contract for Summer 2016.

The original study design and data collection were supported by colleagues at University of Kansas Medical Center including Ed Auer Jr., William Brooks, Carmen Cirstea, Allan Schmitt, and Jeff Searl.

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