Task-Induced deactivations associated with intelligible speech

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Introduction

Speech comprehension studies[1] have generally focused on the isolation and function of regions with positive blood oxygen level-dependent (BOLD) signals with respect to a resting baseline. Although regions with negative BOLD signals compared to resting baseline have been reported in language-related tasks[2], their relationship to regions of positive signals is not fully appreciated. In this study we investigate the relationship between stimulation-induced activation and deactivation during levels of speech comprehension. We specifically ask if the intelligibility of a stimulus induces variable signal deactivations and if those deactivations are only located within the DMN system[3,4]

Based on the emerging notion that negative signals may represent an active function in language tasks, we test the hypothesis that negative BOLD signals during receptive language are more associated with comprehension than content-free versions of the same stimuli.

Materials and Methods

Subjects

15 healthy right-handed subjects, 6 male, 30.5 ± 7.5 years/old.

Imaging

Image acquisition: EPI: TR = 3000, TE = 43, flip angle 60, 21 contiguous slices, FOV= 190 mm, 1.5 x 1.5 x 5 mm voxels, 120 acquisitions/run. Two 6-min runs.

Study Paradigm

Task: passive listening to English narratives that were intelligible (played forward) or unintelligible (reversed and muffled speech).

Design: 9 blocks of 18 sec. (3 blocks/condition) were alternated with 18 sec. rest periods.

Conditions: Personal narratives were used to create 3 conditions

i)natural speech (NS): content was comprehensible,

ii)reversed speech (RS): segment was digitally time-reversed so meaning and prosody were removed, and

iii)muffled speech (MS): band-pass filtered in order to preserve fundamental frequency variability, lexical tone, prosody, and speech rate but to render the content unintelligible.

Analysis

SPM8 (motion correction, spatial smoothing, analysis), CANlab (artifact correction), xjview (anatomical labels, MNI coord.)

GLM contrasts: 1) Listening to Speech (NS+RS+MS>rest), and 2) Speech Comprehension (NS> RS+MS) at $p < 0.001$ ($t \geq 3.79$, uncorrected, extend threshold 40 voxels).

BOLD Signal polarity: Speech comprehension signals were averaged for each condition and resting baseline.

PPI: Used a composite comprehension seed (network seed) of all clusters associated with speech comprehension for each subject.

Results

Fig 1. All listening conditions (Normal, Reversed, and Muffled Speech > Rest). Positive (red) & Negative (blue) signals

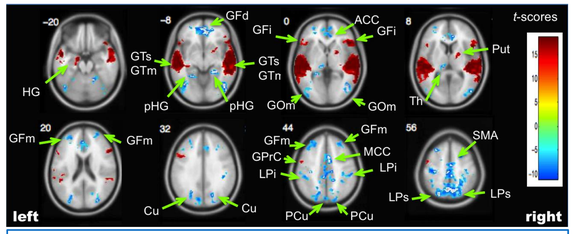


Fig 1. Positive Signal = mostly auditory and language areas, Negative Signal = mostly DMN regions
Lateral temporal cortex (usually part of DMN) has a positive signal.

Fig 2. Activated regions = temporal regions, frontal regions, parahippocampal and hippocampal gyrus, caudate, and thalamus. Time course: positive BOLD signal is above resting baseline for all conditions.

Deactivated regions = frontal regions, parietal regions, occipital regions and right insula. Time course: negative BOLD signal is below resting baseline for the natural speech but close to baseline for reversed and muffled speech (these regions are only engaged during intelligible speech).

Fig 2. Speech comprehension (Normal Speech > Reversed and Muffled Speech). Positive (red) and Negative (blue) regions

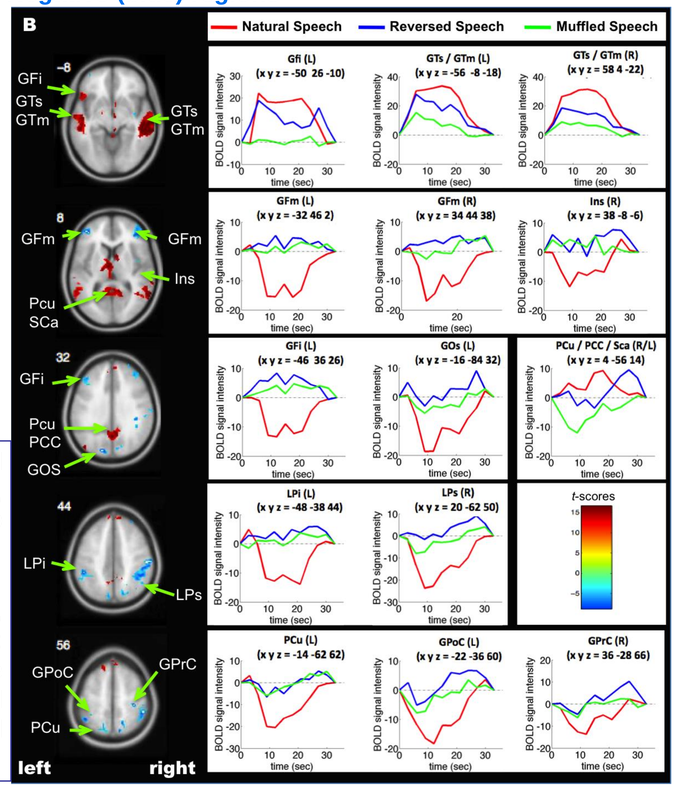
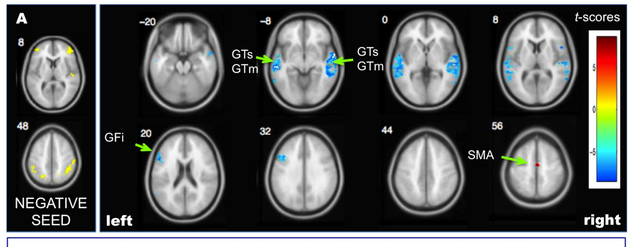
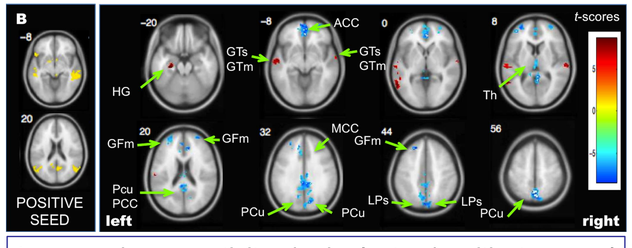


Fig 3. Functional Connectivity of negative signals (from Fig 2.) during language comprehension. Increased (red) and decreased (blue) connectivity.



Increased connectivity (red clusters) with SMA. Decreased connectivity (blue clusters) with canonical language regions (middle and superior temporal, and inferior frontal gyrus) (seen in Fig 1. as activations in red)

Fig 4. Functional Connectivity of positive signals during language comprehension. Increased (red) and decreased (blue) connectivity.



Increased connectivity (red clusters) with temporal cortices, and supramarginal, hippocampal, and postcentral gyrus.
Decreased connectivity (blue clusters) with frontal gyrus, precuneus, medial structures, and thalamus (seen in Fig 1. as deactivations in blue)

Conclusion

- Speech comprehension (natural versus muffled and reversed speech) engages clusters of **positive BOLD signal** with respect to resting baseline within the temporal cortex and frontal lobe as expected.
- Speech comprehension also engages clusters of **negative BOLD signal** with respect to resting baseline within frontal-parietal regions. However, natural intelligible speech, but not unintelligible speech, is associated with the deactivated signal.
- While the amplitude of positive BOLD signal is graded over the three conditions, the amplitude of the negative BOLD signal is not graded and only present during the intelligible speech condition.
- Regions of positive and negative signals were collectively distinguished by their functional connectivity. When speech is meaningful, areas of positive BOLD signal decrease their connectivity to the DMN, and areas of negative BOLD signal decrease their connectivity to the traditional language areas in frontal and temporal cortices.

References

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