Engagement of the Cingulo-Opercular System Enhances Future Word Recognition

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Introduction

The engagement of attention systems is critical for successful communication, particularly when difficult listening conditions diminish speech intelligibility. Speech recognition requires more effort in noise and elicits increased activity in frontal cortices that are collectively referred to as the cingulo-opercular network [CO; 1,2].

The CO network responds to difficulty, response uncertainty, and errors across a range of experimental tasks [3]. Neuroimaging studies involving non-linguistic tasks have shown that CO activity also can predict behavioral adjustments on subsequent trials [4].

The goal of the current study was to assess the extent to which CO network activity predicts word recognition on subsequent trials in a normative sample of young adults.

Predictions:

1. Elevated CO activity provides a word recognition benefit.
2. Coherent CO network engagement improves word recognition.

Method

Participants: 18 young, normal hearing adults [20-38 years, m = 29.2, sd = 5.8; 10 females; native English speakers; right-handed distribution (m = 68.3, sd = 50.3; [7]). Mean pure tone thresholds (200 Hz to 8000 Hz) were less than 9.2 dB HL.

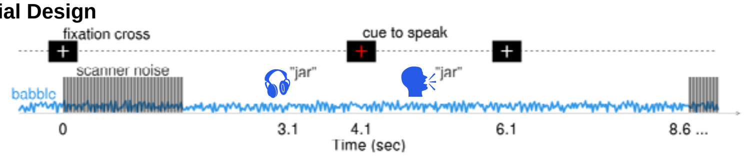
Task: Listen, then repeat the word aloud, or say "nope" if it was not recognizable.

Stimuli: 120 consonant-vowel-consonant words in multi-talker babble.

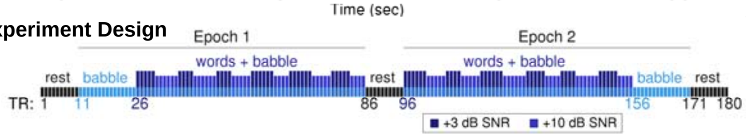
- Multi-talker babble: 82 dB SPL; speech: 85 dB SPL (60 words, +3 dB SNR).
- Multi-talker babble: 82 dB SPL; speech: 92 dB SPL (60 words, +10 dB SNR).
- Words were presented in alternating SNR-blocks of 4-6 trials, 60 trials per epoch.

Word recognition: Correct if the word was repeated exactly as it was presented.

Trial Design



Experiment Design



E-Prime presented scanner-synched stimuli with Sensimetrics piezoelectric insert earphones and recorded responses with a Resonance Technology microphone.

fMRI: 180 T2*-weighted images (3 mm^3 voxels); TR = 8.6 sec; 25 min 48 sec.

Structural MRI: T1-weighted images (1 mm^3 voxels).

Analysis

Preprocessing. Functional images were realigned, co-registered, and smoothed (8mm FWHM), detrended [5], and spatially normalized into the mean sample space derived from the T1-anatomical images [6].

General linear model and group-level SPM analyses were used to examine BOLD responses to babble, words and babble in each SNR condition, in addition to correct or incorrect word recognition trials.

A general linear mixed model (GLMM) analysis was performed to predict trial-level word recognition *(W)* with normalized BOLD activity from the preceding trial in each voxel: $W_t = SNR_t + BOLD_{t-1} + (1|SUB) + error$.

Another GLMM analysis tested the association between the proportion of regions of interest (PROI) with elevated activity for each trial and next trial word recognition: $W_t = SNR_t + PROI_{t-1} + (1|SUB) + error$. Each participant's ROIs were defined independently of their BOLD time series by performing the voxel-level GLMM and leaving that participant out.

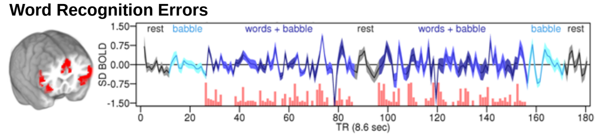
A voxel level threshold of $Z = 3.09$, $p = 0.001$ and cluster extent threshold = 20 voxels, $p_{FWE} < 0.05$ were used for all fMRI results.

Results

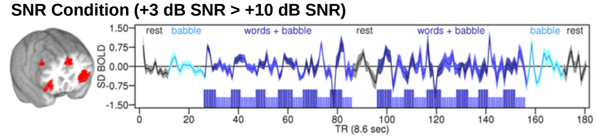
Word Recognition: poorer in the +3 dB SNR (66.1 ± 7.6%) than in the +10 dB SNR (90.9 ± 3.9%), Z = 11.34, p < 0.001.

BOLD Response

Word Recognition Errors

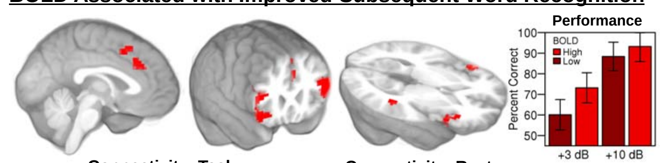


SNR Condition (+3 dB SNR > +10 dB SNR)



CO network activity increased following errors (red bar height denotes mean error for each trial) and during +3 dB SNR trials (dark blue bars) compared to +10 dB SNR trials (light blue bars).

BOLD Associated with Improved Subsequent Word Recognition



Connectivity: Task

R.STS	APC	R.IFG	R.AIFO	L.IFG	
0.38**	0.34**	0.43**	0.48**	0.51**	DPC
	0.17**	0.64**	0.46**	0.46**	R.STS
		0.17**	0.35**	0.27**	APC
			0.51**	0.45**	R.IFG
				0.39**	R.AIFO

Connectivity: Rest

R.STS	APC	R.IFG	R.AIFO	L.IFG	
0.30**	0.15	0.34**	0.40**	0.44**	DPC
	0.12	0.56**	0.29**	0.30**	R.STS
		0.04	0.25**	0.12	APC
			0.31**	0.43**	R.IFG
				0.21**	R.AIFO

CO network activity increased before correct responses, after controlling for SNR effects on activity. Connectivity between CO regions increased during word recognition compared to rest epochs, Z = 4.93, p < 0.001. Correct responses were more likely after more CO regions exhibited elevated activity, Z = 2.03, p = 0.04

Conclusions

Elevated CO activity is frequently observed when speech recognition requires greater effort [1-2, 7-10].

Our results show that CO engagement increases the likelihood of correct word recognition on the next trial, similar to findings in visuospatial studies [4,11]. Furthermore, the trial-level connectivity analysis demonstrated that correct word recognition increased when all regions in the CO network exhibited elevated activity on the previous trial.

These findings are consistent with the premise that the CO network is important for adaptive control, including during word recognition.

References

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