# Anterior Insula and Frontal Operculum Support Word Recognition in Younger and Older Adults

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## Introduction

Speech recognition is difficult for older adults, especially in adverse listening conditions [1]. The degree to which attention systems support speech recognition in older adults is unclear.

Our ability to adapt behavior in challenging environments is supported by neural systems that monitor performance and sustain attention. For example, the cingulo-opercular system is thought to monitor task performance because of its responsiveness to errors and has been linked to increased response latencies on trials that follow errors in young adults [2,3]. Older adults increasingly engage the cingulo-opercular system [4,5,6], which suggests that error monitoring is important for maintaining performance with age.

The current experiment tested the hypothesis that the cingulo-opercular system supports speech recognition, particularly in older adults. We examined the contribution of the cingulo-opercular system to performance on subsequent trials (**post-error** and **post-correct**).

## Method

### Participants

45 participants [19-85 years, m = 45.4, sd = 18.3; 24 females; native English speakers; right-handed distribution (m = 70, sd = 58.9; [7]); normal hearing to moderately sloping sensorineural hearing loss]. Mean pure tone thresholds (250 Hz to 8000 Hz) were correlated with age, r = 0.79, $p < 0.001$.

### Design

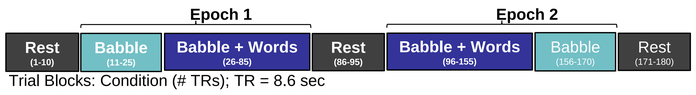
Task: listen, then repeat the word aloud, or say “nope” if it was not recognizable.

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

- Multi-talker babble: 82 dB SPL and speech: 85 dB SPL (60 words, +3 dB SNR).
- Multi-talker babble: 82 dB SPL and speech: 92 dB SPL (60 words, +10 dB SNR).

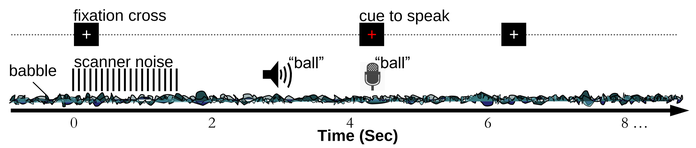
SNR conditions: words in alternating SNR-blocks of 4-6 trials, 60 trials per epoch.

**Experiment Design**




Trial Blocks: Condition (# TRs); TR = 8.6 sec

**Trial Design**




Synchronized with Eprime; Sensimetrics piezoelectronic insert earphones; Resonance Technology microphone.

**Imaging Protocol**

Anatomical: T1-weighted, 1mm$^3$ voxels.

Functional: 180 T2*-weighted images, 25 min 48s; TR = 8.6s; 3 mm$^3$ voxels.

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## Analysis

**Preprocessing.** Functional images were realigned, co-registered, and smoothed (8mm FWHM). Linear Model of the Global Signal [8] was used to detrend the images, which were aligned using diffeomorphic normalization parameters from co-registered T1 images [9].

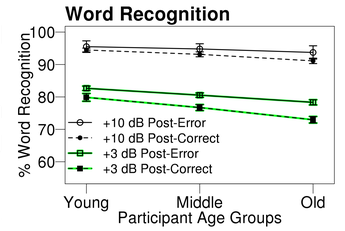
**Analysis.** The General Linear Model included separate event types for babble-only and words+babble trials, with percent correct as a parameter. Group level tests were performed to identify activity that occurred with word recognition errors.

The General Linear Mixed Model [10] was used to predict word recognition, which included normalized BOLD activity (AR-1 corrected) from the preceding TR within each voxel and across subjects. Separate analyses were performed for trials that followed either correct or incorrect responses.

## Results

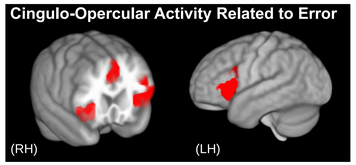
Word recognition: +3 dB SNR < +10 dB SNR [m = 79.2%, 93.9%; t(44) = -20.52, p < 0.001]; correlated with participant age: +3 dB SNR [r(43) = -0.41, p < 0 .005] and +10 dB SNR [r(43) = -0.52, p < 0 .0002].

Specific +3 dB SNR condition effects: Word recognition was lower after a correct response than an incorrect response [m = 76.6%, 80.6%; t(42) = 4.59, p < 0.001]; performance was lower with increasing age: post-error [r(41) = -0.45, p = 0.002] and post-correct [r(41) = -0.48, p = 0.001]; *(removed 2 outliers)*.

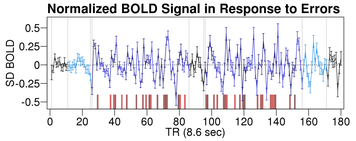



* Plot-groups: Young (Y), Middle (M), Older (O); average ages = 26.6, 42.3, 67.4 years (N = 15 each).

**Cingulo-Opercular Activity Related to Error**



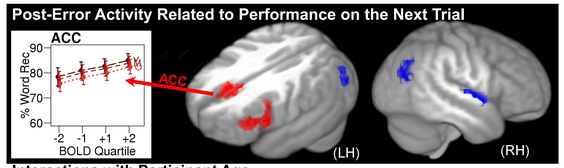

**Normalized BOLD Signal in Response to Errors**



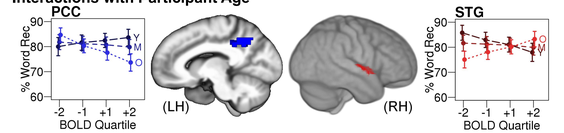

**GLM:** Cingulo-opercular activity in response to errors.

[t(43) > 5.26, $p_{FWE} < 0.05$]

**Post-Error Activity Related to Performance on the Next Trial**



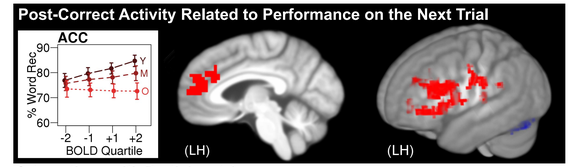

**Interactions with Participant Age**



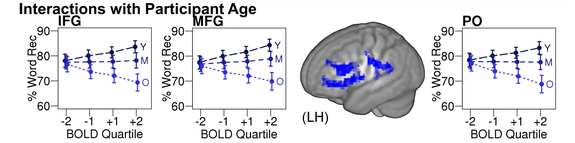

**GLMM post-error:** increased cingulo-opercular activity predicted word recognition in the next trial. Age interacted with activity in posterior cingulate cortex (PCC) and superior temporal gyrus (STG).

[t(970) > 2.33, p = 0.01 (*cluster* $p_{FWE} = 0.05$)].

**Post-Correct Activity Related to Performance on the Next Trial**




**Interactions with Participant Age**




**GLMM post-correct:** anterior cingulate cortex (ACC), inferior frontal gyrus (IFG), middle frontal gyrus (MFG), posterior operculum (PO) were related to word recognition. Negative age interactions with IFG, MFG, PO activity.

[t(1491) > 2.33, p = 0.01 (*cluster* $p_{FWE} = 0.05$)].

## Conclusions

Error detection is important for adapting behavior in challenging task conditions, even in the absence of explicit feedback. Cingulo-opercular responses to error or difficulty have been linked to behavioral adjustments including slower response latencies ([11, 12], i.e., increased *response caution* [13]).

Word recognition improved following errors in the +3 dB SNR condition. Activity in the cingulo-opercular system increased with error and a rise in activity was directly related to word recognition on the next trial. Elevated ACC activity was also associated with performance for the post-correct trials. Performance monitoring can support speech recognition throughout the adult lifespan.

## Citations

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