Cingulo-Opercular Network Support for Word Recognition by Older Adults

KI Vaden, SE Kuchinsky, JB Ahlstrom, JR Dubno, MA Eckert
Department of Otolaryngology-Head and Neck Surgery
Medical University of South Carolina, Charleston, SC

Purpose

Speech recognition in noise often activates a cortical network that includes the dorsal paracingulate, anterior insula, and frontal opercula[1].

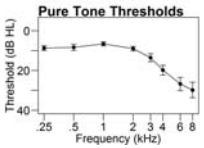
This cingulo-opercular network is hypothesized to monitor performance across many tasks[2] and facilitate adaptive control, as demonstrated by associations between activity and subsequent changes in behavior and performance[3,4].

Cingulo-opercular activity during task performance can increase with age[5,6], particularly for relatively high performing older adults[7,8]. These findings support the premise that increased frontal activations compensate for age-related cognitive and perceptual declines that increase task difficulty (e.g., CRUNCH[7], PASA[8]).

We used a mixed modeling approach to test the adaptive control and frontal compensation predictions that elevated cingulo-opercular activity occurs prior to word recognition for older adults.

Methods

Participants: 31 older adults (50-81 years of age; m = 60.2, sd = 8.1; 19 female; 15.5 ± 2.3 years of education. Hearing loss predominantly affected sensitivity at frequencies > 2kHz.



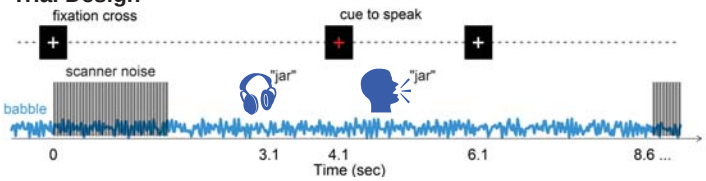
Task: Listen, then repeat the word aloud, or say "nope" if it was not recognizable.

Stimuli: 120 words presented in multi-talker babble (82 dB SPL).
60 words: 85 dB SPL (+3 dB SNR).
60 words: 92 dB SPL (+10 dB SNR).

Words were presented individually in blocks of 4-6 trials with alternating SNR conditions, in two epochs with 60 trials each.

Correct recognition: word repeated exactly as it was presented.

Trial Design



E-Prime was used to present acquisition-synchronized stimuli with Sensimetrics piezoelectric insert earphones and record responses with a Resonance Technology microphone.

fMRI: 180 T2*-weighted (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[9], and spatially normalized into the mean sample space derived from the T1-anatomical images[10].

General linear mixed model (GLMM) analyses were performed on voxel time series to test the prediction that trial-level word recognition *(W)* was related to normalized BOLD contrast from the preceding trial ($BOLD_{t-1}$):

$$W_t = SNR_t + BOLD_{t-1} + SNR_t \times BOLD_{t-1} + (1|SUB) + error.$$

Model testing was used to remove factors that did not significantly contribute to model fit. A voxel level threshold (Z = 2.33, p = 0.01) and family wise error corrected cluster extent threshold (43 voxels, $p_{FWE} < 0.05$) were used in combination for the fMRI results. Individual effects were estimated from the clusters that were predictive of correct word recognition, then compared to participant age and mean word recognition to test individual differences predictions.

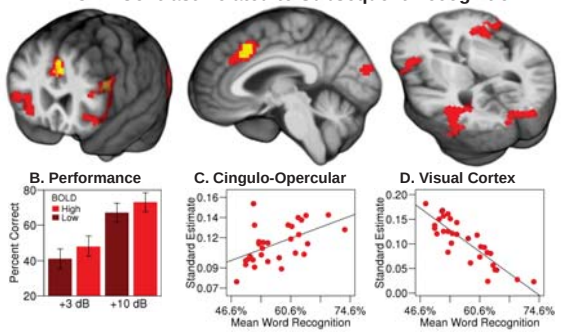
Results

Word Recognition was poorer in the +3 dB SNR (42.6 ± 6.8%) than in the +10 dB SNR (70.4 ± 7.3%), Z = 13.61, p < 0.001.

BOLD Contrast and Subsequent Word Recognition

A. Elevated activity in cingulo-opercular regions was associated with an increased likelihood of correct recognition on the next trial.

B. Correct recognition was 7.0% and 5.9% more likely in the +3 and +10 dB SNRs, respectively, when comparing trials preceded by high versus low activity.



C. Participants with better overall word recognition demonstrated larger trial-level cingulo-opercular effects (r = 0.53, p = 0.002). Cingulo-opercular effects were not related to participant age (r = -0.12, p = 0.53).

D. Occipital and occipito-temporal activity also predicted recognition on the next trial, but with larger individual effects in older participants (r = 0.37, p = 0.04) who had poorer overall word recognition (r = -0.87, p < 0.001).

Discussion

Consistent with adaptive control and frontal compensation predictions[7,8], elevated cingulo-opercular activity predicted word recognition on the next trial across 50-81 year olds, particularly those with the best performance.

Aging effects were observed in visual cortex that could reflect declines in frontal suppression[11-13] (e.g., onscreen response cues) or alternative strategies that intermittently increase visual cortex activity (e.g., eye-closing). The associations between visual cortex and performance are consistent with either explanation.

Conclusion

Cingulo-opercular activity appears to provide a normative word recognition benefit for older adults, as well as younger adults[1]. In contrast, visual cortex associations with aural word recognition in the poorest performers and oldest participants may be an early marker of age-related declines in our sample of healthy older adults.

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