Cortical Activity and Incidental Memory for Speech in Noise

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Introduction

Memory is poorer for speech identified in noise, especially for older adults (Murphy et al., 2000; Rabbitt, 1968; 1991; Ward et al., 2016). Cognitive resources are thought to be allocated to aid identification, at the expense of encoding (Heinrich et al., 2008; Tun et al., 2009).

Activity in cingulo-opercular regions of frontal cortex increases during difficult listening tasks, more extensively for older adults (Eckert et al., 2009; Erb and Obleser, 2013; Harris et al., 2009; Vaden et al., 2013; 2015). This activity is proposed to engage cognitive resources to optimize performance (Eckert et al., 2016; Vaden et al., 2013).

Cingulo-opercular engagement is predicted to limit memory encoding, particularly for older adults who may be more reliant on cognitive resources for word identification in noise. However, memory experiments that control perceptual difficulty indicate this activity facilitates successful encoding (Kim, 2011; Spaniol et al., 2009).

A delayed recognition memory task was performed to test predictions that cingulo-opercular activity during word identification in noise relates to better or worse memory.

Methods: Experiment Design

An fMRI study with two tasks (encoding, memory test) was used to examine incidental encoding during word identification in noise.

The initial sample included 22 participants (10 males, *M* age = 29.8 ± 5.9 years; normal hearing). A follow-up sample to test aging effects included 24 older adults (11 females, *M* age = 61.9 ± 13.6 years, *M* pure tone thresholds = 11± 7.7 dB HL for 0.5 to 2 kHz).

Task 1 – Encoding: Word identification in multi-talker babble (+3 or +10 dB SNR). Participants repeated each word aloud or said "nope". Memory maintenance strategies were limited by giving Task 2 instructions only after Task 1 concluded.

Task 2: Recognition memory test with band-pass filtered words above 0.2 kHz and below 0.4, 1, 1.6, 3.15 kHz. Participants responded by button-press to indicate if they: 1) remembered, 2) did not remember, or 3) could not understand the word.

fMRI: 3 mm^3 voxels; Task 1: 180 volumes, 25 m 48 s; Task 2: 150 volumes, 21 m 30 s. **MRI:** T1-weighted images (1 mm^3 voxels).

Methods: Analyses

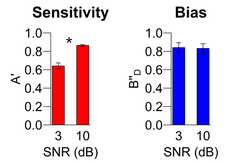
Signal detection theory measures were used to test SNR effects on delayed recognition memory: sensitivity and response bias.

	Task 2: Delayed Recognition	
Task 1: Word Identification in Noise	Button: Remember	Button: Don't Remember
Word presented AND correctly repeated	*Memory Hit*	*Memory Miss*
Word not presented OR not identified	*False Alarm*	*Correct Rejection*

The fMRI analysis examined BOLD contrast during encoding (Task 1) that related to hits or misses in the delayed recognition memory test. Results from the initial sample were used to functionally define cingulo-opercular regions of interest.

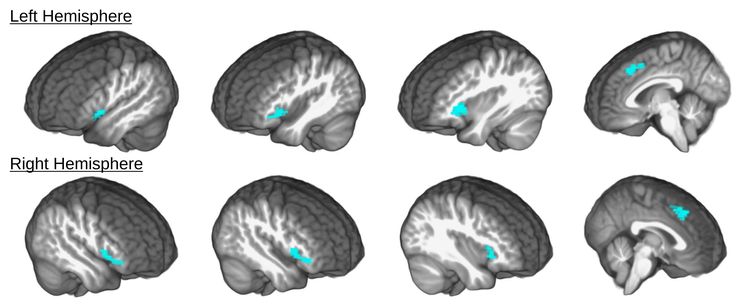
Results

Correctly identified words in Task 1 presented at +10 dB SNR were more likely to be remembered than those at +3 dB SNR [$t(19) = 6.54$, $p < 0.001$]. A false-negative bias was observed [$t(19) = 16.90$, $p < 0.001$] with no SNR difference [$t(19) = 0.25$, *ns*].



Left: Average memory sensitivity (A') scores during the delayed recognition memory test are shown with SEM error bars. Memory sensitivity was significantly different for words from each SNR. The false negative bias ($B''_D > 0$) indicates that subjects were likely to respond that they did not remember a word from either SNR.

Cingulo-opercular activity was elevated during the challenging word identification in noise task, however activity decreased for correctly identified words that were later not remembered.



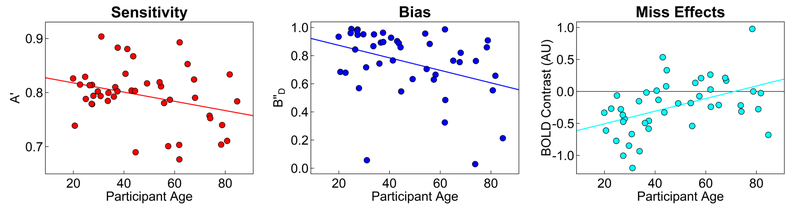
Above: During encoding, cingulo-opercular BOLD was significantly lower for words that were *misses* in the delayed recognition memory task (cyan), compared to the other words. These significant ***miss effects*** were defined with a combined voxel statistic: $Z = 3.09$, $p_{UNC} = 0.001$ and permutation-based cluster extent: $p_{FWE} < 0.05$ threshold (Eklund et al., 2014). Results are shown on a study-specific average brain template.

Age-Related Individual Differences

Results: The older adults (N = 24) had better memory sensitivity for words in the +10 dB SNR than +3 dB SNR [$t(23) = 7.83$, $p < 0.001$], and no SNR difference in bias [$t(23) = 0.96$, *ns*].

For the combined samples (N = 44), increasing participant age was related to poorer sensitivity [$r = -0.31$, $p = 0.04$], less negative bias [$r = -0.36$, $p = 0.02$], and weaker memory-miss effects on cingulo-opercular BOLD during encoding [$r = 0.46$, $p = 0.002$].

Stepwise regression tests determined that age (not hearing loss) best predicted sensitivity, bias, and cingulo-opercular miss effects.



Above: Memory sensitivity (A') significantly decreased, the false negative response bias (B''_D) significantly decreased, and cingulo-opercular activity lapses during encoding of the miss-words were less negative with increasing participant age.

Conclusions

Consistent with the memory literature (Spaniol et al., 2009; Kim, 2011), delayed recognition memory was poorer for correctly identified words accompanied by lower cingulo-opercular activity.

Decreased activity could reflect lapses in task-focused attention (Eichele et al., 2008; Weissman et al., 2006), or attention misdirected from speech in noise during encoding (Wild et al., 2012).

Passive or incidental memory encoding appears to benefit from more extensive cognitive processing (Craik and Tulving, 1975), so less engaged attention may limit processing and encoding of words.

Our aging results suggest that sustained and elevated attention provides limited benefit to encoding for older adults, and that other declines (e.g., hippocampal function) could negatively affect passive memory encoding for speech in noise.

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