Memory Encoding for Middle-Age and Older Adults During Word Identification in Noise

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Introduction

Older adults have difficulty remembering speech that is understood in difficult listening conditions (e.g., noise) [1-6].

Difficult listening tasks increase demand for attention and performance monitoring, which is reflected in higher frontal cortex activity [7-9] and can occur with poorer memory recognition after a time delay [10-12].

Successful delayed memory recognition for individual items has also been linked to elevated frontal cortex activity during encoding [13], including correctly understood words in noise for younger adults [5].

The function and structure of frontal cortex regions that support memory encoding appear to decline with older age [14] and with age-related hearing loss [15]. These declines could contribute to poorer memory for words in noise for middle-age and older adults.

We examined how middle-age and older adults encode words into memory by assessing the link between brain activity during word identification in noise and delayed memory recognition.

Methods

Participants

N = 42, 30 female, 50-80 years of age [M = 65], normal hearing to moderate hearing loss [M PTA = 14 dB HL, 0.25 to 3 kHz, both ears].

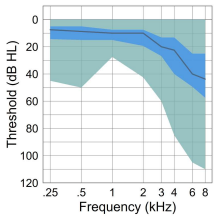

Figure 1: Average pure-tone threshold 25% quantiles for the study participants, across ears.

Task 1 – Encoding task

Words starting with /b/ or /p/ were presented with insert earphones at 88 dB SPL in a speech-shaped noise (+15 dB SNR).

The participants were instructed to repeat each word in this fMRI experiment, which also examined voicing effects on perception and memory. Memory test instructions were given after the fMRI experiment concluded to limit the use of memory maintenance strategies.

- **Sparse, Multi-band fMRI:** Quiet period between scans (7 s) for stimulus presentation and response recording. TR = 8.6 s, TA = 1.63 s, 2.5 mm^3 voxels, 151 volumes, total duration = 21 m 39 s.
- **Structural MRI:** MP2RAGE T1-weighted images (1 mm^3 voxels).

Task 2 – Recognition memory test

After MRI scanning, participants were instructed to select the words that they remembered from Task 1 from a list of 24 words (12 foils).

Results: Word Identification and Memory

Signal detection theory measures (sensitivity and bias) were used to characterize delayed recognition memory.

Word identification was significantly higher for /p/ words than /b/ words, but memory for /p/ and /b/ words was not significantly different.

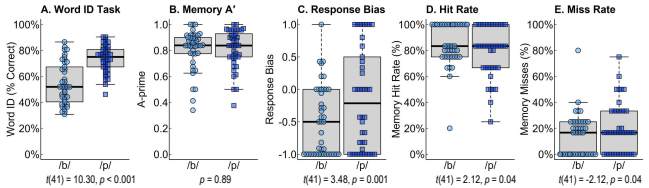

Figure 2: Word identification and memory task performance for /b/ versus /p/ words across participants. **A.** Correct identification of /p/ words was significantly higher than /b/ words [PTA: r = -0.35, p = 0.02; age: p = 0.21]. **B.** Memory accuracy (A′): not significantly different for /b/ and /p/ words, when controlling for response bias. **C.** Response bias (B''_D): The /b/ words were more likely to be reported as remembered than /p/ words, based on negative-signed B''_D. The memory and bias measures were not significantly associated with age and PTA [ps > 0.10] (not shown).

Results: Word Identification in Noise

BOLD activity was elevated during word identification in noise.

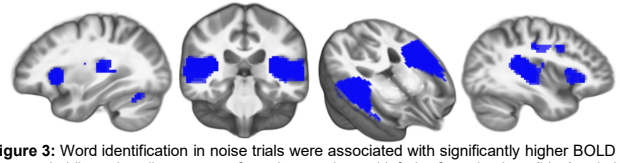

Figure 3: Word identification in noise trials were associated with significantly higher BOLD contrast in bilateral auditory cortex, frontal opercula, and inferior frontal sulcus (blue), relative to the baseline. Significant task-related effects were defined with a combined voxel statistic: Z = 3.09, p_{UNC} = 0.001 and Family-Wise Error-corrected cluster extent threshold: p_{FWE} < 0.05. Results are shown on the study-specific average brain template from the study participants.

BOLD activity was higher for the more difficult /b/ compared to /p/ condition.

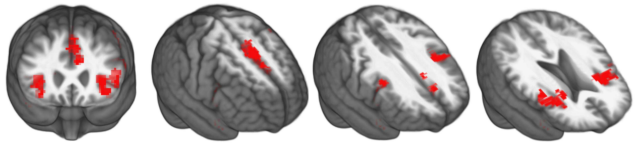

Figure 4: Significantly higher BOLD contrast was observed for regions that included the dorsal cingulate, bilateral inferior frontal gyrus and operculum, and bilateral inferior frontal sulcus for the more difficult /b/ words compared to the easier /p/ words (red), when accuracy was included in the model. This pattern of cingulo-opercular activity in frontal cortex is typically seen when comparing easier and harder conditions.

Results: Encoding Words into Memory

BOLD activity was higher for the memory hits compared to the other words.

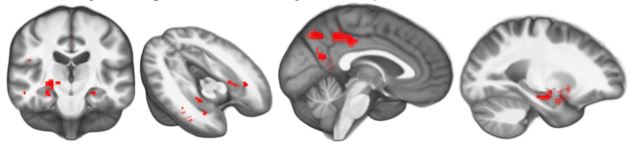

Figure 5: During word identification in noise, significantly higher activity was observed in bilateral hippocampus, basal forebrain, and precuneus for words that were later successfully remembered (memory hits) relative to all other word presentations. Significant effects used a combined thresholds: Z = 1.64, p_{UNC} = 0.01 and corrected cluster extent (p_{FWE} < 0.05).

BOLD activity was lower for the memory misses compared to the other words.

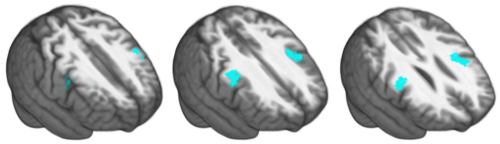

Figure 6: Significantly lower activity was observed in the left inferior frontal sulcus and right precentral sulcus for correctly identified words that were later not remembered (memory misses). These miss effects were not significantly different for /b/ and /p/ words [p = 0.79].

Conclusions

Established memory-related brain regions (e.g., hippocampus) showed higher activity for the understood words that were later remembered, consistent with memory encoding [16-19].

Reduced frontal cortex activity during encoding appears to contribute to memory failures [5,17,18]. The inability to sustain frontal cortex activity may explain why older adults have difficulty remembering information heard in difficult listening conditions.

In the context of this study, frontal cortex activity may be considered a limited resource over time, where sustained activity may be necessary to encode speech into memory [5,9].

Our ongoing work examines why sustained activity may be important for encoding and the factors that may limit sustained activity.

Acknowledgements. This work was supported by the National Institutes of Health / National Institute on Deafness and Other Communication Disorders (P50 DC 00422), MUSC Center for Biomedical Imaging, and South Carolina Clinical and Translational Research (SCTR) Institute, NIH/NCRR Grant number UL1 RR029882. This investigation was conducted in a facility constructed with support from Research Facilities Improvement Program, NIH/NCRR Grant number C06 RR14516. We also thank the study participants.

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