An fMRI Study of Age-Related Changes in Sustained Attention and Word Recognition

KI Vaden, SE Kuchinsky, SL Cute, JB Ahlstrom, JR Dubno, MA Eckert

Department of Otolaryngology-Head and Neck Surgery
Medical University of South Carolina, Charleston, SC

MUSC COLLEGE of MEDICINE

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Introduction

- Difficult listening conditions require increased attention to recognize speech (Davis & Johnsrude, 2003; Eckert et al., 2009; Oblesser et al., 2007; Sharp et al., 2006).
- Declines in the ability to maintain attention may underlie reductions in the ability to understand speech in challenging environments, especially for older adults (Tun et al., 2009).
- The current study aimed to characterize age-related changes in attention networks that may be critical for word recognition in difficult conditions.
- We predicted that sustained engagement of the dorsal attention network (DAN), implicated in cognitive control, would be associated with superior word recognition. In contrast, sustained activation of the ventral attention network (VAN), which appears to be involved in task monitoring, would be more likely to reflect poor word recognition (Dosenbach et al., 2006; Eckert et al., 2009).

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; Oldfield, 1971)]. Mean pure tone thresholds were positively correlated with age, r = 0.79, $p < 0.001$.

Task Design

- Stimuli: 120 consonant-vowel-consonant words in multitalker babble.
- Task: listen, then repeat the word aloud, or say "nope" if the word was not recognizable.
- Intelligibility: multitalker babble at 82 dB SPL and speech at 85 dB SPL (+3 dB SNR); multitalker babble at 82 dB SPL and speech at 92 dB SPL (+10 dB SNR).
- SNR conditions: words in SNR-blocks of 4-6 trials, 60 trials per epoch (+3 dB SNR: 60 trials, +10 dB SNR : 60 trials).
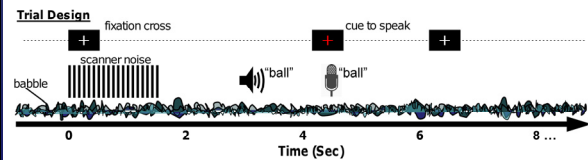

Imaging Protocol

Anatomical: T1-weighted, 1mm³ voxels.

Functional: 180 T2*-weighted images, 25 min 48s; TR = 8.6s; 3 mm³ voxels.

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

Analysis

Preprocessing. SPM5 realignment, co-registration, smoothing (8mm FWHM). Linear Model of the Global Signal (Macey et al., 2004) was used to de-trend the functional images, which were normalized with the Advanced Normalization Tools (ANTS, Avants et al., 2011) using the T1 images.

fMRI Analysis. A General Linear Model was used to include separate event types for babble-only trials and words+babble trials, which were convolved with the hemodynamic response function. Group level tests were performed to identify task-related activity and changes related to trial number within epochs of babble and words+babble. Subsequent region of interest (ROI) tests were based on group statistic maps.
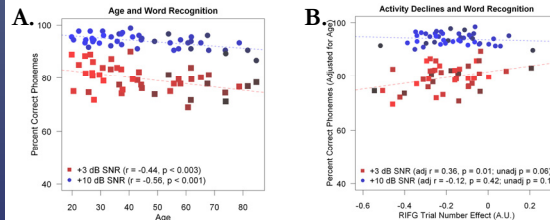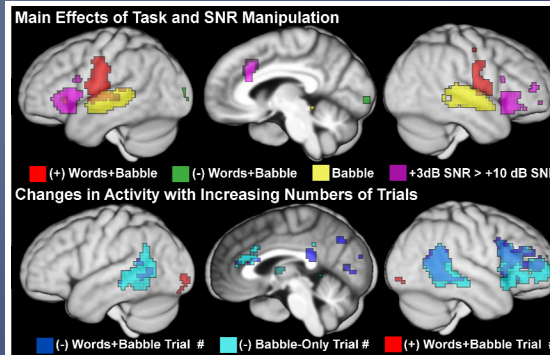

Results

Top: Increased VAN activity occurred for the +3 dB versus +10 dB SNR conditions (right hemisphere, purple).

Middle: Attention and auditory networks exhibited decreased activity with increasing trial number. Statistic maps are thresholded at t(44) = 5.27, p = 0.05 (Family-wise error corrected).

Bottom: A. Increased age predicted lower word recognition. **B.** Subjects with increasing VAN activity across the epochs had higher word recognition scores for the +3 dB SNR condition, as larger VAN decreases were associated with lower word recognition scores.
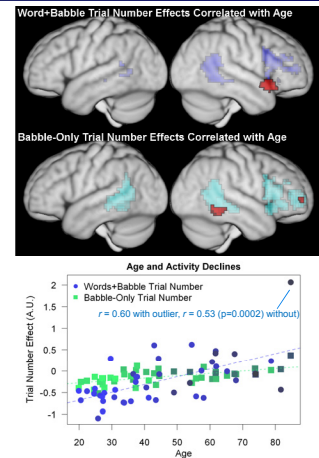
Above: VAN activity decreased more for younger adults than older adults. Mean pure tone thresholds were weakly correlated with activity declines, although correlated with age.

Conclusions

- **The ventral attention network disengaged across each words+babble and babble-only epoch of the experiment.**
- Older adults sustained VAN activity to a greater extent than younger adults, which is consistent with findings of increased right frontal activity across task demands (Cabeza, 2002; Cabeza et al., 2002).
- Independent of age effects on performance, VAN declines were related to increased errors for +3 dB SNR trials (poor intelligibility). The unexpected engagement of the VAN, instead of the DAN, in people with superior word recognition performance may reflect the need to maintain attention to salient features (words) in an unpredictable environment (babble) and/or consideration of competing responses.

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