# DECLINING STRUCTURAL INTEGRITY OF SPEECH-RELATED TEMPORAL LOBE CORTEX PREDICTS AGE-RELATED DECLINES IN WORD RECOGNITION

**Mark A. Eckert, Kelly C. Harris, Noam I. Keren, Jayne B. Ahlstrom, Judy R. Dubno**

Medical University of South Carolina, Department of Otolaryngology, Charleston, S.C.

## Introduction

- Speech recognition becomes more difficult and effortful with age, even for normal hearing listeners (van Rooij and Plomp, 1990; Dubno et al., 1997) .
- Speech recognition is particularly affected in older adults when listening conditions are demanding (Sommers and Danielson, 1999; Gordon-Salant and Fitzgibbons, 2001, 2004; Dubno et al., 2005, 2006).
- Neural systems that support cognitive control are engaged in demanding listening conditions (Eckert et al., 2008; Oblesser et al., 2007).
- Age-related increases in the engagement of cognitive control systems have been observed, as demonstrated by increased frontal activity during perceptual and memory tasks (Fernandes et al., 2006; Moffat et al., 2006; Cabeza et al., 1997; Grady et al., 2007; Rypma and D'Esposito, 2000).
- We examined the extent to which age-related structural and functional changes within speech and cognitive control systems predicted age-related declines in word recognition.

## Methods

### Participants

| | Younger | Older |
|---|---|---|
| Age | 28.8 (6.7) | 70.5 (5.9) |
| Gender (♀/♂) | 12/6 | 13/5 |
| Edinburgh Handedness | 90.0 (9.7) | 94.4 (9.4) |

### Functional Imaging

- Sparse sampling image acquisition: TR=8 s, TA=1.64 s, TE=30 ms, 36 slices, 64 x 64, 3 mm thick.
- Realignment, artifact analysis, normalization, and 8mm kernel smoothing was performed using the Artifact Repair Toolbox and SPM5.

**Figure 1.** Sparse sampling design of the word recognition experiment in which 120 nouns and verbs were presented in one of 4 filter conditions to vary word intelligibility.

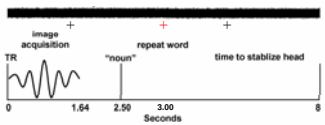
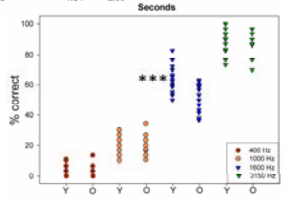



**Figure 2.** Word recognition in the scanner for each filter condition across individuals and between groups (Y -younger; O - older). Note the group difference for the 1600 Hz condition (t=3.77, p<.001).




### Structural Imaging

- Image Acquisition: TR = 8.13 ms, TE = 3.7 ms, 160 slices, 256 x 256, 1 mm thick.
- Unified segmentation and DARTEL normalization (Ashburner and Friston, 2005; Ashburner, 2007) were performed to normalize, segment, and bias field correct the images. Temporal lobe speech intelligibility (**Fig 3**) and frontal lobe task performance fMRI results (**Fig 4**) were used to limit voxel based analyses to speech and attention-related brain regions.

## Results

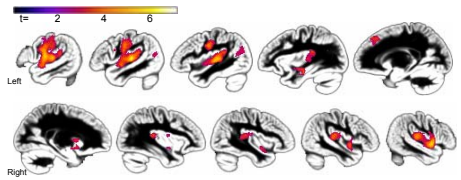



**Figure 3.** Group results demonstrating increasing activity with parametric increases in word intelligibility (peak voxel p<.01, cluster p<.01; overlaid on the study specific template used to normalize the functional and structural images). These results are consistent with previous studies of word intelligibility showing increasing anterior temporal activity with increasing speech intelligibility (Scott et al., 2006; Obleser et al., 2007; Eckert et al., 2008). There were no age group differences in responsiveness to word intelligibility and individual variability in hearing loss was not related to the degree of responsiveness for word intelligibility in older adults.

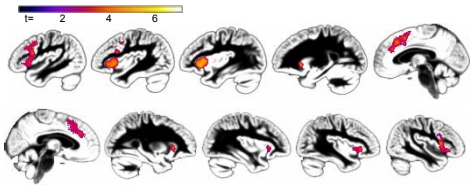



**Figure 4.** Group results demonstrating increasing anterior cingulate cortex (ACC) and bilateral anterior insula / frontal operculum activity for incorrect vs. correct responses (peak voxel p<.01, cluster p<.01). Similar results were observed for decreasing word intelligibility.

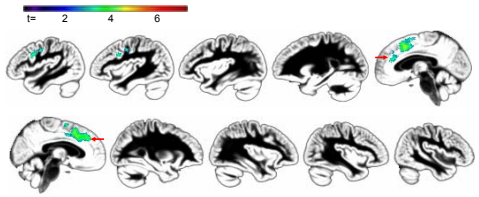



**Figure 5.** Age group differences in frontal activation for the incorrect vs. correct comparison. Younger adults engage these regions consistently when making incorrect responses, while older adults appear to engage the same regions across correct and incorrect responses. The ACC / supplementary motor activation (arrows) is related to declines in auditory cortex volume shown in **Fig 7**.

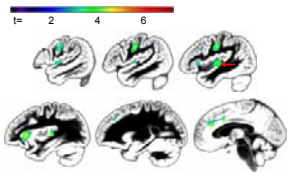
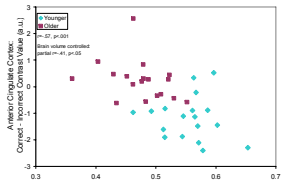
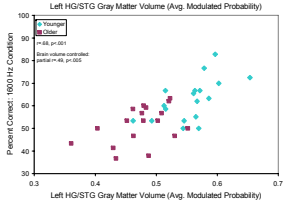
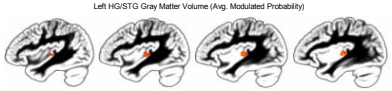



**Figure 6.** Younger adults exhibit greater gray matter volume than older adults within speech and attention-related regions shown in **Figs 3** and **4** (FDR p<.05). Note the left Heschl's gyrus / superior temporal gyrus (HG/STG) and ACC age group differences (arrows).



**Figures 7,8,9**. **Top**: scatter plot showing that individual variation in left hemisphere auditory cortex significantly predicts ACC activation (**Fig 5**); **Middle**: scatter plot showing that individual variation in left hemisphere auditory cortex significantly predicts word recognition specifically in the 1600 Hz condition (**Fig 4**); **Bottom**: auditory cortex gray matter voxels contributing to the relation with word recognition seen above.

## Discussion

- The results of this study indicate that the speech recognition difficulty experienced by older adults stems, in part, from declines in speech-related auditory cortex.
- The results of this study also are consistent with evidence that speech recognition is particularly affected in older adults when listening conditions are demanding (Dubno et al., 2005). Indeed, the relation between word recognition and speech-related auditory cortex was most robust when words were recognizable, but difficult to recognize because of filtering.
- The association between speech-related auditory cortex morphology and word recognition was independent of the degree of hearing loss. This indicates that both age-related declines in peripheral and central auditory systems contribute to the communication problems of older adults. The significance of central declines may be most prevalent in challenging listening conditions where top-down modulation may enhance speech recognition.
  - The association between speech-related auditory cortex and word recognition was present within older and younger groups, suggesting that developmental factors influencing auditory cortex morphology contribute to word recognition. We hypothesize that older adults with neurobiologically based language learning disability may be at particular risk for age-related speech recognition problems.
- The age-related change in ACC activation appears to reflect the engagement of the ACC regardless of whether older adults made a correct or incorrect response The results of this study suggest that increased engagement of conflict and error monitoring systems are a consequence of structural declines in speech-related auditory cortex.

## References

Ashburner J. A fast diffeomorphic image registration algorithm. Neuroimage 38(1):95-113, 2007.
Ashburner J, Friston KJ. Unified segmentation. Neuroimage 26: 839-851, 2005.
Cabeza R, Grady CL, Nyberg L, McIntosh AR, Tulving E, Kapur S, Jennings JM, Houle S, Craik FI. Age-related differences in neural activity during memory encoding and retrieval: a positron emission tomography study. J Neurosci 17: 391-400, 1997.
Dubno JR, Lee FS, Matthews LJ, Mills JH. Age-related and gender-related changes in monaural speech recognition. J Speech Lang Hear Res 40: 444-452, 1997.
Dubno JR, Horwitz AR, Ahlstrom JB. Recognition of filtered words in noise at higher-than-normal levels: decreases in scores with and without increases in masking. J Acoust Soc Am 118: 923-933, 2005.
Eckert MA, Walczak A, Ahlstrom J, Denslow S, Horwitz A, Dubno JR.Age-related effects on word recognition: reliance on cognitive control systems with structural declines in speech-responsive cortex. J Assoc Res Otolaryngol. 9(2):252-9, 2008.
Fernandes MA, Pacurar A, Moscovitch M, Grady C. Neural correlates of auditory recognition under full and divided attention in younger and older adults. Neuropsychologia 44: 2452-2464, 2006.
Gordon-Salant S, Fitzgibbons PJ. Sources of age-related recognition difficulty for time-compressed speech. J Speech Lang Hear Res 44: 709-719, 2001.
Grady CL, Yu H, Alain C. Age-Related Differences in Brain Activity Underlying Working Memory for Spatial and Nonspatial Auditory Information. Cereb Cortex, 2007.
Moffat SD, Elkins W, Resnick SM. Age differences in the neural systems supporting human allocentric spatial navigation. Neurobiol Aging 27: 965-972, 2006.
Obleser J, Wise RJ, Alex Dresner M, Scott SK. Functional integration across brain regions improves speech perception under adverse listening conditions. J Neurosci 27: 2283-2289, 2007.
Rypma B, D'Esposito M. Isolating the neural mechanisms of age-related changes in human working memory. Nat Neurosci 3: 509-515, 2000.
Scott SK, Rosen S, Lang H, Wise RJ. Neural correlates of intelligibility in speech investigated with noise vocoded speech--a positron emission tomography study. J Acoust Soc Am 120: 1075-1083, 2006.
Sommers MS, Danielson SM. Inhibitory processes and spoken word recognition in young and older adults: the interaction of lexical competition and semantic context. Psychol Aging 14: 458-472, 1999.
van Rooij JC, Plomp R. Auditive and cognitive factors in speech perception by elderly listeners. II: Multivariate analyses. J Acoust Soc Am 88: 2611-2624, 1990.

## Acknowledgements

We would like to thank the AFAR Southeast Affiliate for supporting this research, the participants of this study, and the MUSC Center for Advanced Imaging Research. This investigation was conducted in a facility constructed with support from Research Facilities Improvement Program Grant Number C06 RR14516 from the National Center for Research Resources, National Institutes of Health.