INCREASING RELIANCE ON COGNITIVE CONTROL SYSTEMS FOR WORD RECOGNITION WITH DECLINING STRUCTURAL INTEGRITY OF SPEECH SYSTEMS

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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 become increasingly engaged in increasingly demanding listening conditions (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 (Grady et al., 1994; 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 cognitive control systems are increasingly engaged with age during a word recognition task in which words were parametrically filtered to manipulate listening demands.

Methods

Participants

- Female/Male: 9/6.
- Age range: 21-75 years, mean=42 years.
- Strongly right-handed (Edinburgh index = 92 (±16)).
- Normal hearing (< 25 dB HL from 250 to 3000 Hz).

Functional Imaging

- Sparse sampling image acquisition: TR=8s, TA=1.64s, TE=30ms, 36 slices, 64x64, 3mm thick.
- Realignment, artifact analysis, normalization, and 8mm kernel smoothing was performed using the Artifact Repair Toolbox and SPM5.

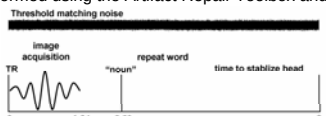

Figure 1. Sparse sampling design of the word recognition experiment in which 40 nouns were presented across 4 filter conditions to vary word intelligibility.

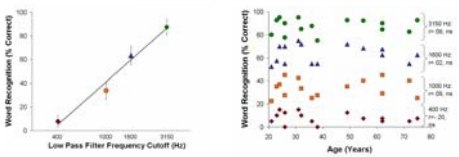

Figure 2. Performance (group mean) for each filter frequency cutoff (left) and across individual listener's age (right). Age did not predict word recognition for each filter condition.

Structural Imaging

- Image Acquisition: TR = 8.13 ms, TE = 3.7 ms, 160 slices, 256x256, 1 mm thick.
- Unified segmentation (Ashburner and Friston, 2005) was performed to normalize, segment, and bias field correct the images. Results from the increasing word intelligibility analysis (Figure 3) were used to limit voxel based analyses to speech-related brain regions.

Results

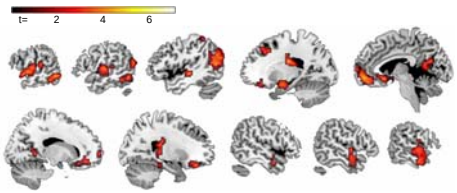

Figure 3. Group results demonstrating increasing activity with parametric increases in word intelligibility (peak voxel p<.01, cluster p<.01). These results are consistent with previous studies of word intelligibility showing increasing anterior temporal activity with increasing speech intelligibility (Scott et al., 2006; Obleser et al., 2007).

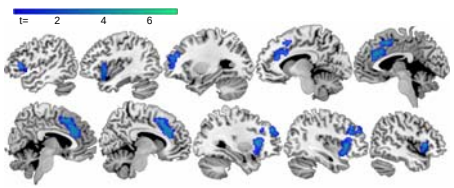

Figure 4. Group results demonstrating increasing anterior cingulate (ACC), anterior insula, inferior frontal gyrus (IFG) and middle frontal gyrus (MFG) activity with decreasing word intelligibility (peak voxel p<.01, cluster p<.01).

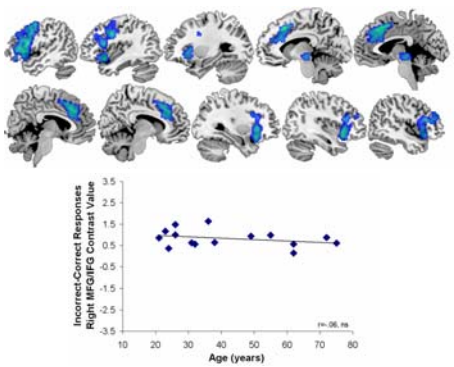

Figure 5. The frontal results seen in Figure 4 are also seen to a greater extent and magnitude when comparing activation for incorrect vs. correct word recognition (peak voxel p<.01, cluster p<.01). The graph shows that contrast values in the right MFG/IFG cluster do not exhibit an age-related change, in contrast to the left MFG shown in Figure 6.

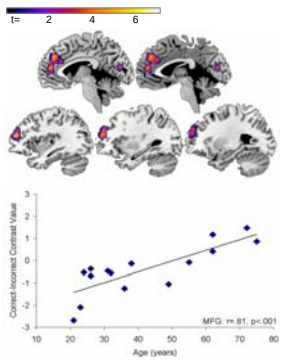

Figure 6. Older adults are more likely to engage left MFG and ACC regions during correct word recognition while younger adults are more likely to engage these regions during incorrect word recognition (peak voxel p<.01, cluster p<.01).

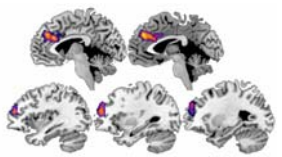

Figure 7. The age-related results presented in Figure 6 remain significant after controlling for filter conditions (peak voxel p<.01, cluster p<.01).

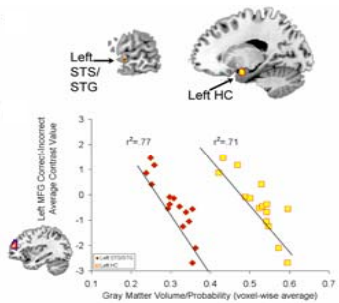

Figure 8. Gray matter declines in speech-related temporal lobe and hippocampal regions predict the age-related increase in frontal activity during correct word recognition (peak voxel p<.05 FWE).

Discussion

- Age-related changes in left MFG and ACC activity were observed during word recognition in clinically normal hearing adults.

  These results are consistent with the results of previous studies demonstrating age-related changes in frontal activity during visual perception and memory tasks (Grady et al., 1994; Fernandes et al., 2006; Moffat et al., 2006; Cabeza et al., 1997; Grady et al., 2007; Rypma and D'Esposito, 2000).

  In particular, the results are consistent with evidence that high functioning older adults are more likely to engage left frontal regions compared to lower functioning older adults who are more likely to engage right frontal regions as well.

  Preliminary analyses of our follow-up study to this project show that poor word recognition is related to increased right frontal activity in older adults, which is consistent with evidence that age-related changes in frontal activity are related to task performance.

- Gray matter declines in left anterior superior temporal and hippocampal regions predicted the age-related left MFG increases in older adults, even after controlling for total gray matter volume.

  This result suggests that people with declining structural integrity of speech-related brain regions rely on cognitive control systems to perform word recognition tasks.

- We hypothesize that structural declines in speech-related systems produce an increased reliance on cognitive control systems for normal word recognition, leading to conversational fatigue that many older adults experience. Perturbation of cognitive control systems may result in a failure to inhibit competing sensory stimuli and impaired speech recognition.

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