Different Neuroanatomic Correlates of Phonemic and Semantic Verbal Fluency in Healthy Adults

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INTRODUCTION

Verbal fluency tasks are frequently administered to assess various neurological and psychiatric disorders or conditions.

Qualitative aspects of generativity on verbal fluency tasks are thought to reflect the organization and dynamics of the underlying semantic network.

On these tasks, clustering refers to the automatic generation of words within a sub-category. In contrast, switching to a new cluster after exhausting a sub-category is thought to be a more effortful process.

Evidence from diverse patient populations suggests that these processes depend on the integrity of several distinct brain circuits. In patients, semantically-guided fluency, and clustering in particular, appear related to temporal lobe structures. Evidence suggests that frontal systems subserve performance on tests of phonemically-guided fluency as well as the ability to efficiently switch between subcategories.

Whether neuroanatomic variability in these regions relates to individual differences in fluency abilities among healthy adults in unclear. Here we investigate the neuroanatomic correlates of automatic and effortful processes during verbal fluency tasks in healthy adults using voxel-based morphometry (VBM).

METHODS

Participants

Participants included 25 adults who served as non-familial healthy normal controls in a study of bipolar disorder and schizophrenia. They reported no history of head injury and were free of medical or psychiatric illnesses thought to impact brain structure or function.

Table 1. Participant Demographics

Age (years, SD)	44.7 (12.4)
Sex (men, %)	14 (56%)
Ethnicity (white, %)	18 (72%)
Education (years, SD)	14.6 (2.3)
NART IQ (mean, SD)	109.9 (11.8)

All participants underwent comprehensive neuropsychological testing and brain magnetic resonance imaging (MRI). Productions on four one-minute trials of phonemic (S and P) and semantic (animals and supermarket items) fluency were coded according to guidelines developed by our group (Ledoux et al., 2009) based on Troyer et al. (1997). Our ratings are designed to capture additional qualitative aspects of lexical retrieval.

Our ratings yielded the following dependent measures:

Total Correct Words	Sum of all words produced, minus rule breaks and repetitions
Clusters	Strings of contiguous words that are related, according to the scoring guidelines
Switches	# of transitions between clusters, including single word clusters (i.e., # Clusters – 1)
Total Cluster Size	# of words, starting with the second word, in multi-word clusters. For single-word clusters, Total Cluster Size = 0
Mean Cluster Size	The size of multi-word clusters, calculated by dividing Total Cluster Size by # of Clusters

MRI Procedures

All participants underwent brain MRI on the same 3T Siemens Trio scanner. We acquired 160 contiguous 1.2 mm MPRAGE images in the coronal plane. These images were preprocessed in SPM5 (Wellcome Department of Cognitive Neurology, Institute of Neurology, University College, London, UK) using MATLAB 7.6 (The MathWorks, Natick, MA, U.S.A.). The unified segmentation method of SPM5 (Ashburner and Friston, 2005) does not require the use of a custom template and was used to analyze the brain tissue concentrations and regional brain volumes. Segmentations were smoothed using an isotropic 12 mm FWHM kernel.

Statistical Analyses

Fluency scores were correlated with regional grey matter (GM) densities after adjusting for age, handedness, and global GM volumes. Statistical analyses were thresholded with an extent of 25 voxels, and based on uncorrected p-values < 0.001.

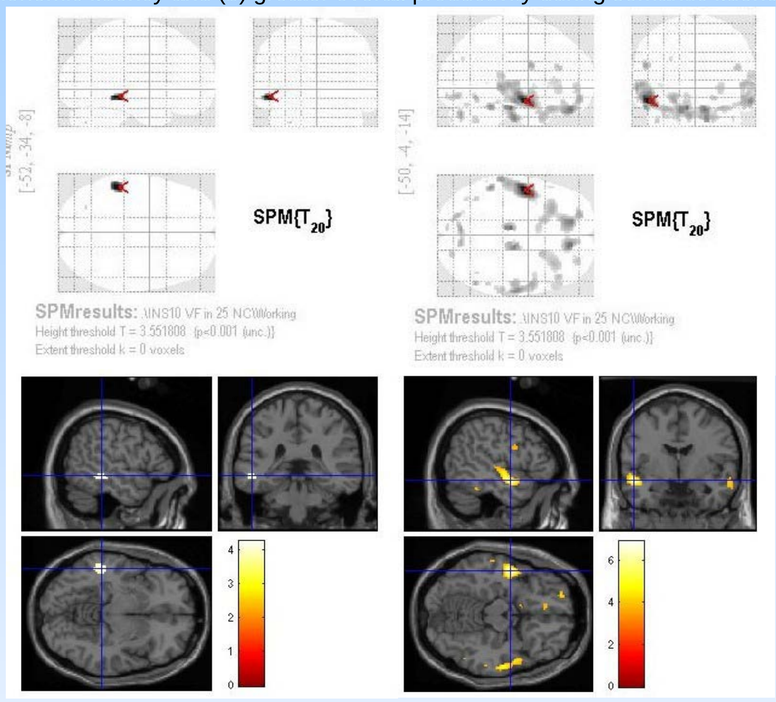
RESULTS

More frequent clustering/switching during phonemic fluency was associated with greater GM densities in the left middle temporal gyrus ($p < 0.001$), corresponding to Brodmann Area 21.

Overall verbal productivity during semantic fluency correlated positively with GM densities in several regions of the frontal and temporal lobes ($p < 0.001$). These include the bilateral anterior prefrontal cortex (Brodmann Area 10) and left temporal pole (Brodmann Area 38), as well as the left inferior temporal gyrus (Brodmann Area 37) and right middle temporal gyrus (Brodmann Area 21).

There were no brain regions in which total cluster size or mean cluster size were significantly associated with localized densities of GM for either letter or semantic fluency at the $p < 0.001$ level.

Figure 1. Statistical parametric maps showing regions in which greater GM densities are correlated with (a) more frequent clustering and switching during phonemic fluency and (b) greater overall productivity during semantic fluency.



Note. Images in neurological space. The color bar represents T-values

CONCLUSIONS

In contrast to evidence derived from studies of Alzheimer disease, Parkinson disease, and frontotemporal degeneration, rates of clustering/switching by healthy adults during a phonemic fluency task was associated with tissue densities in temporal regions subserving auditory processing and language, but not the frontal lobes.

On tests of semantic fluency, overall productivity was associated with the integrity of brain regions underlying strategic processes related to memory retrieval, auditory processing and language, word recognition, and within-category identification.

Our findings support the notion that different neurocognitive networks underlie various qualitative aspects of speeded verbal productivity, both in healthy adults as well as patient populations.

REFERENCES

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ACKNOWLEDGEMENTS

This research was supported by the Therapeutic Cognitive Neuroscience Gift Fund.