

Temporal and Structural Contributions to Activation of Anterior Temporal Sentence Processing Regions: an fMRI Study

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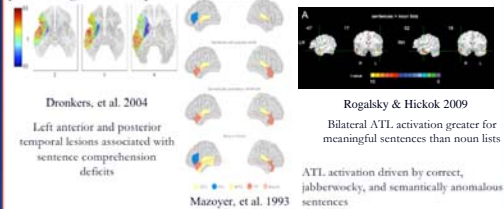
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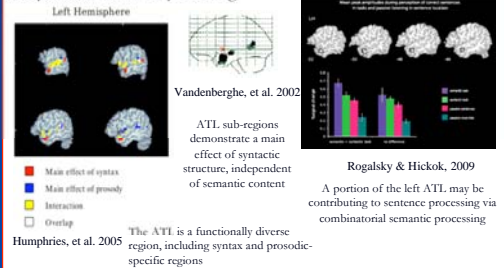


Introduction

Identification of neural circuits supporting sentence-level processing remains an important but elusive goal in cognitive neuroscience. Although Broca's area has long been the central focus of this investigation, recent imaging and lesion studies have implicated the anterior temporal lobe (ATL) in sentence processing, for example:



The ATL has particularly been implicated in syntactic computation and compositional semantic processing:



The ATL is a functionally diverse region, including syntax and prosodic-specific regions

Current Study

The exact nature and specificity of the computations of regions active during sentence processing, including the ATL, remains controversial. Specifically, the ATL may be involved in:

- **General temporal integration** (not sentence-specific)
- **Hierarchical structure building** (specific to structured stimuli such as sentences and melodies)
- **Syntactic processing** (sentence-specific)

Thus, in the present fMRI analysis we compare the hemodynamic response of the ATL to spoken and melodic stimuli whose hierarchical structure and presentation rate have also been manipulated.

Predictions about the ATL:

If the ATL is a general resource for integrating information over time, ATL activity will be mostly modulated by presentation rate, independent of stimulus type.

If the ATL is responsive to hierarchical structure in general, sentences and melodies will equally drive activation, at a given presentation rate. In addition, activity should be modulated as a function of rate for both sentences and melodies.

If ATL activity is driven by syntactic computations, then sentences, in comparison to word lists and melodies, will elicit greater ATL activity. In addition, the presentation rate of sentences (but not melodies or scrambled sentences) should modulate activation.

Stimuli

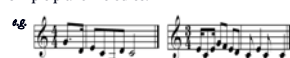
Jabberwocky sentences:

- It is the glander's klen in my nederopit. Illindale may be wazzing by for swall.

Scrambled jabberwocky sentences:

- nederopit my in klen glandar's the is it swall for by wazzing be may illindale

Simple piano melodies:



3 versions of each stimulus were generated:
 - normal speech/play rate
 - 30% slower than normal
 - 30% faster than normal

fMRI Design

Mixed event-related/block design:



Each block contains only one stimulus type, but a random combination of the 3 presentation rates

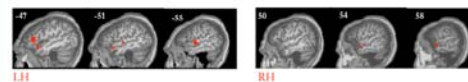
TR = 2, full brain volumes collected

20 subjects, 3T scanner (UCI Research Imaging Center)

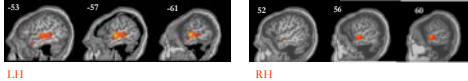
We used a multiple regression analysis with regressors for each stimulus type at each presentation rate to identify bilateral sentence-processing regions.

At the normal presentation rate:

sentences > scrambled sentences:



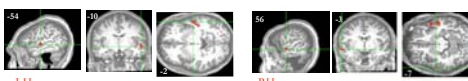
sentences > melodies:



Bilateral regions more active for sentences than for scrambled sentences or melodies, at the normal presentation rate (voxel-wise paired-samples t-test, $p < .0005$)

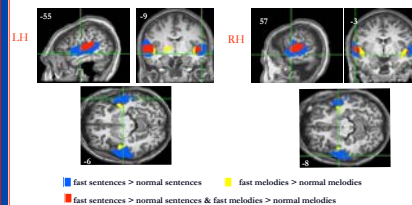
Overlap of

sentences > scrambled sentences & sentences > melodies, normal presentation rate:



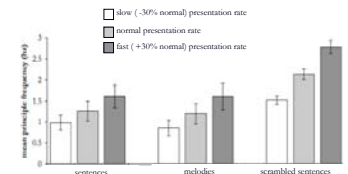
Explicit Rate Manipulation Effects

Conjunction of voxels more active during the presentation of sentences and/or melodies within the fast presentation rate versus the normal presentation rate: (voxel-wise paired-samples t-tests, $p < .005$)



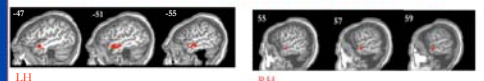
Contributions of Acoustic Information in the Localization of Sentence-Processing Regions

The amount of acoustic information being presented per unit time varies between the three stimuli types at each presentation rate, as characterized by the mean principle frequency component of each stimulus type's acoustic envelope:

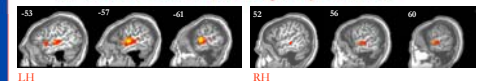


Thus, we performed an additional multiple regression analysis for each subject, using the principle frequency component of each stimulus as a covariate:

sentences > scrambled sentences, w/ frequency covariate:



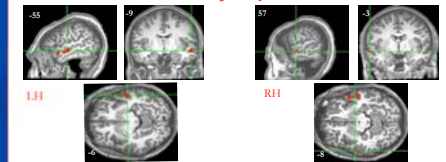
sentences > melodies, w/ frequency covariate:



Bilateral regions more active for sentences than for scrambled sentences or melodies, when the mean frequency component is a covariate (voxel-wise paired-samples t-test, $p < .0005$)

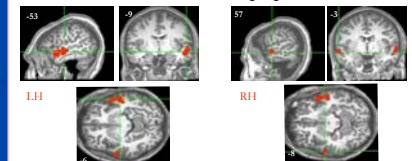
Overlap of

sentences > scrambled sentences & sentences > melodies, With frequency covariate:



Modulations Related to Sentence Acoustic Properties

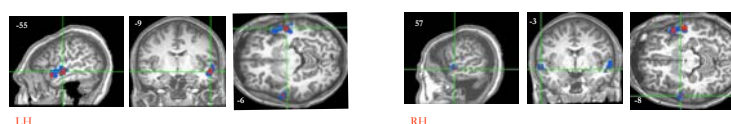
modulation by sentences' acoustic properties > scrambled sentences & melodies acoustic properties:



Overlap of voxels whose activation are more accounted for by the principle frequency components of the sentences than the principle frequency components of the melodies and scrambled sentences, respectively, $p < .0005$.

Effects of Rate vs. Stimulus Type in the ATL

modulation by sentences' acoustic properties and/or by sentence structure:



Conjunction of voxels across subjects that (i) are modulated more by the principle frequency components of the sentences than the principle frequency components of both the melodies and scrambled sentences, and/or (ii) are more active during the presentation of sentences compared to both melodies and scrambled sentences when the principle frequency component of each stimulus' envelope is included as a covariate ($p < .0005$).

Summary

- As suggested by previous research, the ATL was implicated in sentence processing (sentences > scrambled sentences & sentences > melodies).
- Although prosodic and/or acoustic information related to sentence structure appears to modulate ATL activity, the presence of sentence structure, after accounting for frequency component differences, results in an increase in ATL activity.
- Overall, our findings support the hypothesis that linguistic and musical structural-processing may recruit overlapping, but not identical hierarchical processing cortical networks.