

A tale of two hubs: a multi-voxel similarity analysis of semantic composition types in left anterior temporal lobe and angular gyrus

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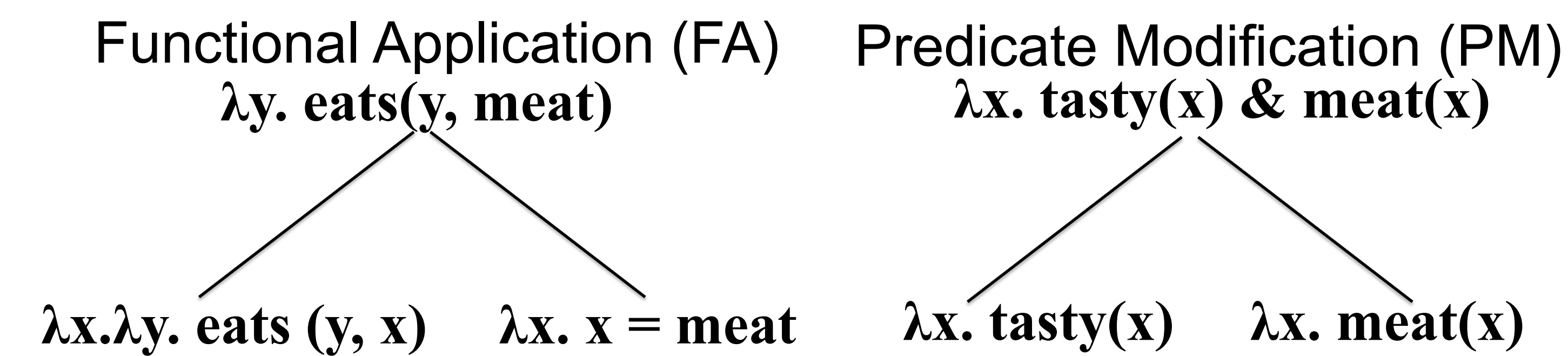
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Introduction

The left anterior temporal lobe (LATL) and left angular gyrus (LAG) have been dubbed “semantic hubs” due to their reliable involvement in multi-modal semantic processing and conceptual combination. However, it is unclear which aspects of semantic composition each area subserves. Work on adjective-noun pairs demonstrates the LATL is sensitive to “feature-based” combinatorics, whereby meaning is derived by combining concepts’ features (Baron et al., 2011; Bemis & Pykkänen, 2011). LAG, on the other hand, has been implicated in tracking event structure and thematic relations between concepts (Graves et al., 2010). One prediction emerging from these studies is that LATL subserves “feature-based” combination of predicates with other predicates, formalized as Predicate Modification (PM), while LAG is more sensitive to “function-based” thematic relations of the sort that arise when a predicate is combined with its arguments (formally Functional Application (FA)) (Heim & Kratzer, 1998).

Hypothesis I: LAG tracks FA (while LATL tracks PM)



However, it is unknown whether LAG might be sensitive to Functional Application in general, which derives meaning for both verb and non-verb phrases (e.g. prepositional phrases), or to the event structure and valency of verbs in particular (Thompson et al., 2007).

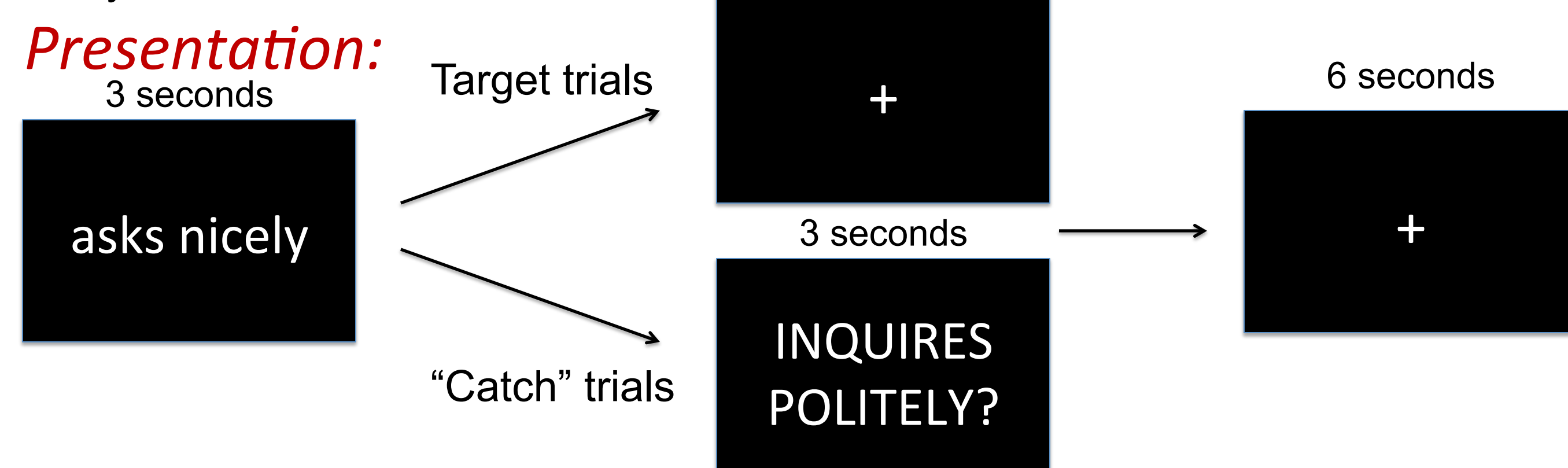
Hypothesis II: LAG tracks event structure and thematic roles; i.e. verbs

Stimuli and Design

36 sets of 4 compositional phrases and 2 non-compositional phrases (noun/verb + non-pronounceable letter string, counter-balanced for word being phrase-initial or -final) +verb_FA, -verb_FA, and -verb_PM always had the same noun, +verb_FA and +verb_PM always had the same verb

	Functional Application (FA)	Predicate Modification (PM)
+verb	<i>eats meat</i> VERB NOUN	<i>eats quickly</i> VERB ADV
verb control	<i>eats fghjl</i> VERB #####	<i>fghjl eats</i> ##### VERB
-verb	<i>with meat</i> PREP NOUN	<i>tasty meat</i> ADJ NOUN
noun control	<i>fghjl meat</i> ##### NOUN	<i>meat fghjl</i> NOUN #####

Task: Subject indicated by button press (yes/no) the synonymy of either a phrase to a preceding compositional phrase or a single word to a preceding non-compositional phrase; e.g. red ball... crimson sphere? OR fghjl ball... sphere? 10% of trials had a probe word/phrase (“catch trials”), 30% of which were not synonymous. Catch trials were excluded from analysis.



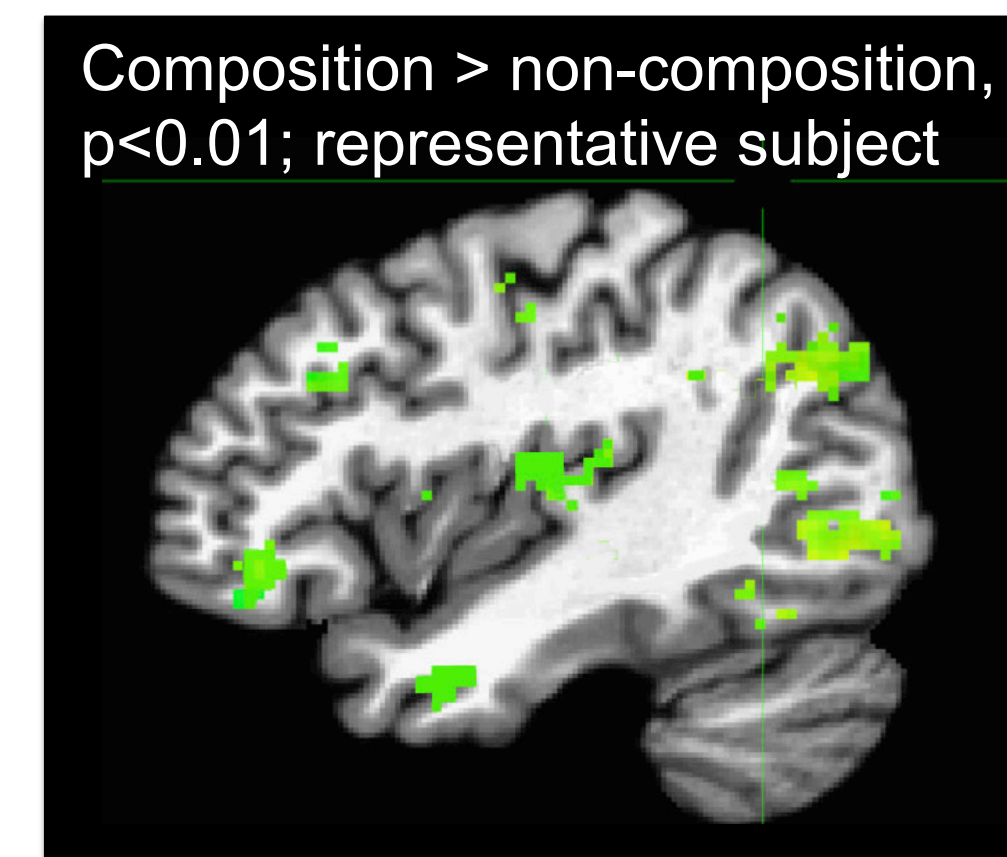
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Methods

Subjects: 18 subjects (6 male) recruited from the University of Pennsylvania, all right-handed native speakers of English.

Voxel Selection

- *Composition > non-composition mask*: AFNI glm over whole-brain Composition (e.g. *eats meat*) > Non-composition (e.g. *eats fghjl*) comparison



fMRI acquisition:

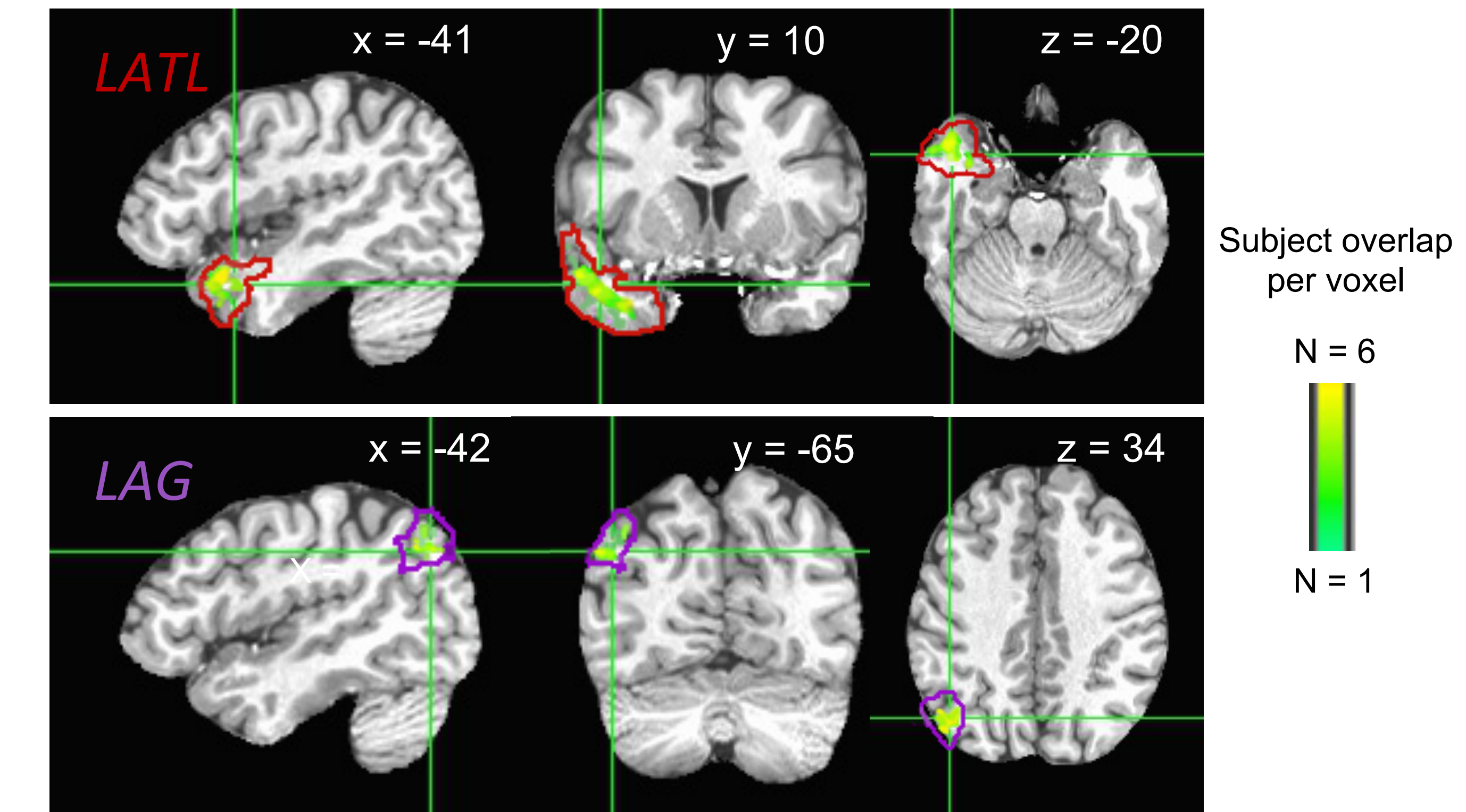
- TR = 3 sec
- 2x2x2 mm voxel size
- B0 unwarping
- Oblique acquisition at +20° from AC-PC

- *Anatomical ROI masks*: From AFNI’s CA_ML_18_MNIA atlas. LATL = left temporal pole + left medial temporal pole. LAG = left angular gyrus

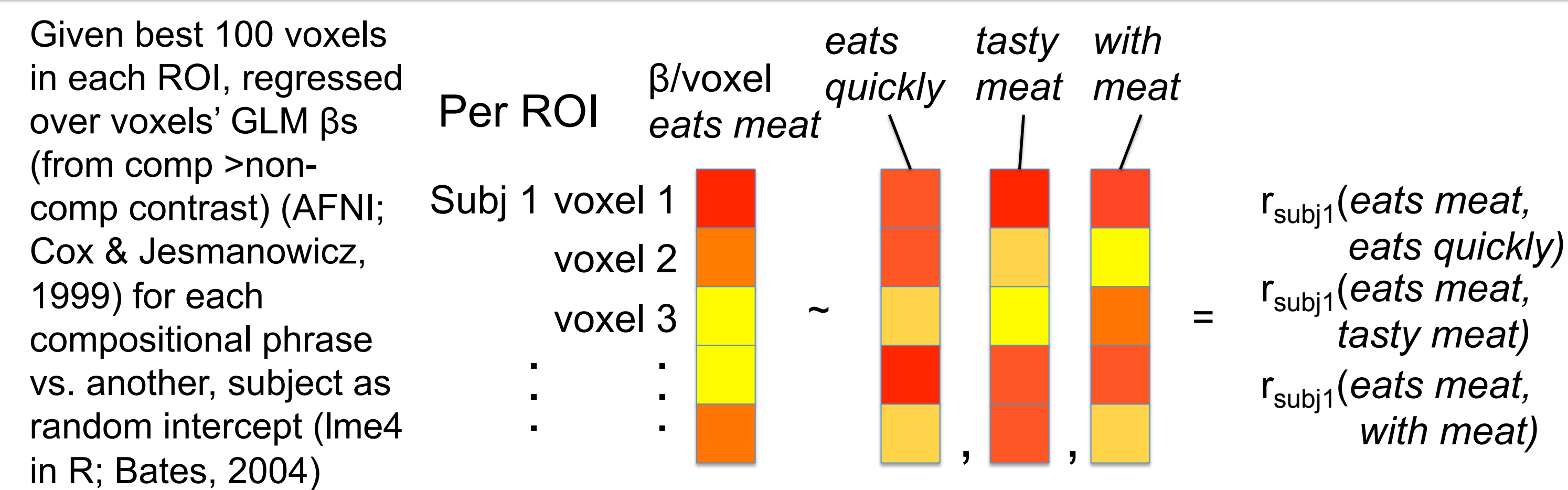
- *Input to similarity analysis*:
 Extracted best 100 voxels (highest t- values) per subject per ROI from Composition > Non-composition comparison

Voxel Heat Maps

- Map of overlap of 18 subjects’ 100 best voxels. ROI boundaries circumscribe heat map.



Similarity Analysis



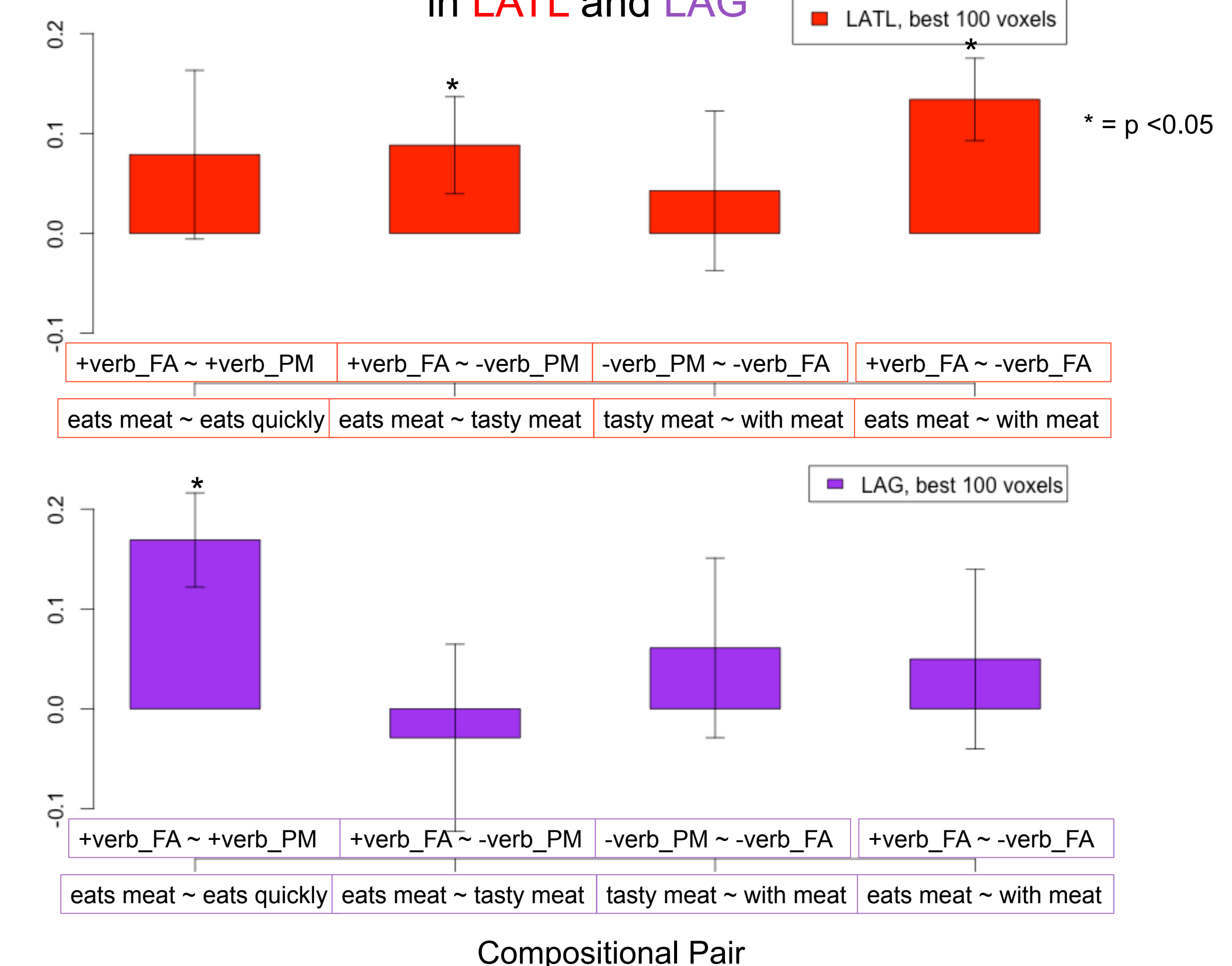
ANOVA over Fisher’s z-transformed correlation values:
 Factors: *Verb* (same verb, different, no verb); *Composition* (same, different); *ROI* (LATL, LAG)

- Post hoc t-test in each ROI:
- shared vs. different *Composition* was only significant in LATL ($p < 0.001$)
 - shared vs. different/no *Verb* was only significant in LAG ($p < 0.001$)

Main effect of *Verb* ($F = 15.936, p < 0.001$)
 Interaction between *Verb* and *ROI*: ($F = 18.346, p < 0.001$)
 Interaction between *Composition* and *ROI* ($F = 8.179, p < 0.01$)

Summary: Suggests that LATL might be sensitive to composition type and/or that the noun (e.g. meat) is the main substrate of similarity between phrases, e.g., between “eats meat” and both “tasty meat” and “with meat” in LATL. LAG tracks similarity of verb structure rather than composition type per se.

Correlation of each pair of word pairs (e.g. *eats quickly* ~ *eats meat*) in LATL and LAG



Conclusion

We assessed multi-voxel pattern similarity profiles of LATL and LAG in response to compositional word pairs sharing either composition type (PM or FA) or event structure (presence or absence of a verb). We find evidence that LAG is more sensitive to verb structure similarity than composition type, while LATL may be sensitive to composition type and/or features combining with nouns.

Acknowledgments

Thanks to the labs of Sharon Thompson-Schill and John Trueswell for their advice and input. This research was supported by grants R01MH70850, R01EY021717 (Sharon Thompson-Schill) and NNC P30 NS45839 (Center for Functional Neuroimaging).