Brain network connectivity during morpholexical processing: an MEG/EEG study

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Introduction

Determining the dynamics of functional connectivity is necessary to understand how and when different sources of information are processed in the neural language system. We contrast two types of processing complexity:

Linguistic processing complexity - indexed by the presence of a potential grammatical morpheme (e.g. played) - engages primarily left lateralised processes [1].

General processing complexity - indexed by competition between lexical alternatives (e.g. claim/clay) - engages a more bilateral network.

Previous fMRI research [1,2] has focused on the spatial distribution of these cortical activities, leaving their temporal dynamics poorly understood. We use MEG/EEG methods to explore the specific spatio-temporal patterns of cortical activity evoked by spoken words.

Predictions

- Left lateralised effects due to the presence of an inflectional morpheme (indexed as IRP: Inflectional Rhyme Pattern) should emerge as evidence accumulates that this pattern is present in the signal.
- Effects of increased general processing complexity should emerge bilaterally as evidence accumulates for the presence of an onset-embedded lexical competitor [2].
- We combine standard univariate analysis with functional connectivity analysis that measures cross-cortical oscillation [3,4]. These methods give us direct measure of the relationship between combinatorial computation in speech recognition and cross-cortical communication between brain areas.

Methods

Subjects

Seventeen adult, right-handed, native English speakers. They listened to lists of spoken words and occasionally performed a one back memory task (10%).

Stimuli

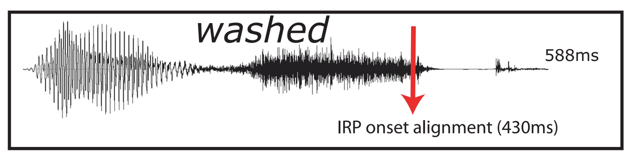
80 items per condition, matched on length, lemma and word form frequency, ngram frequency, and N size.

Condition	Examples	Embedded stem	IRP
Past Tense	Played	? (play)	Y
Stem, No IRP	Claim	Y (clay)	N
No stem, No IRP	Cream	N	N

Acquisition & preprocessing

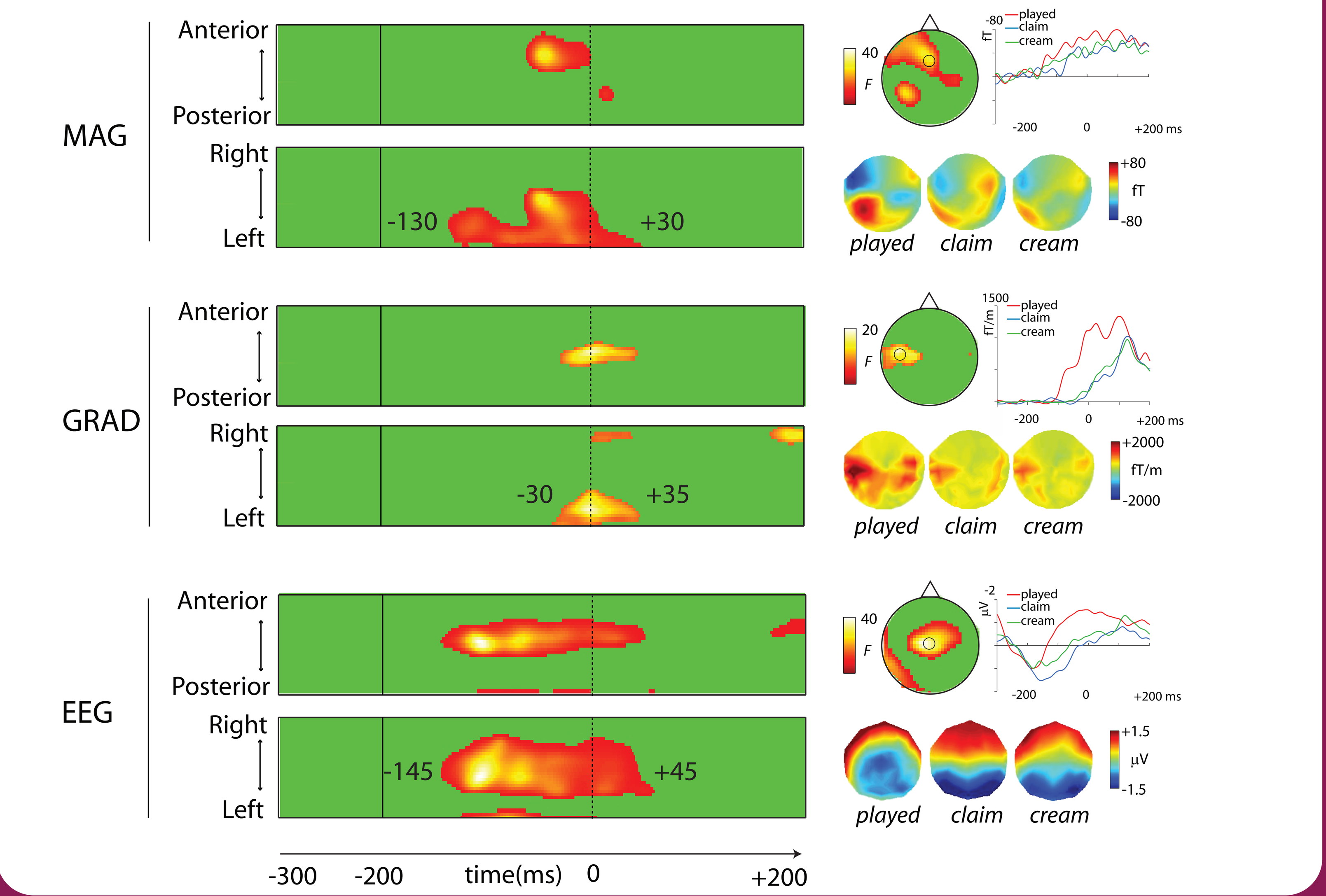
MEG/EEG (306-channel MEG, 70-channel EEG Vectorview system) and three-compartment boundary-element forward models (source reconstruction) using structural MRI scans (3T) [5].

Epochs (-200 to +200ms) were aligned to the **IRP onset** (closure preceding final stop release).

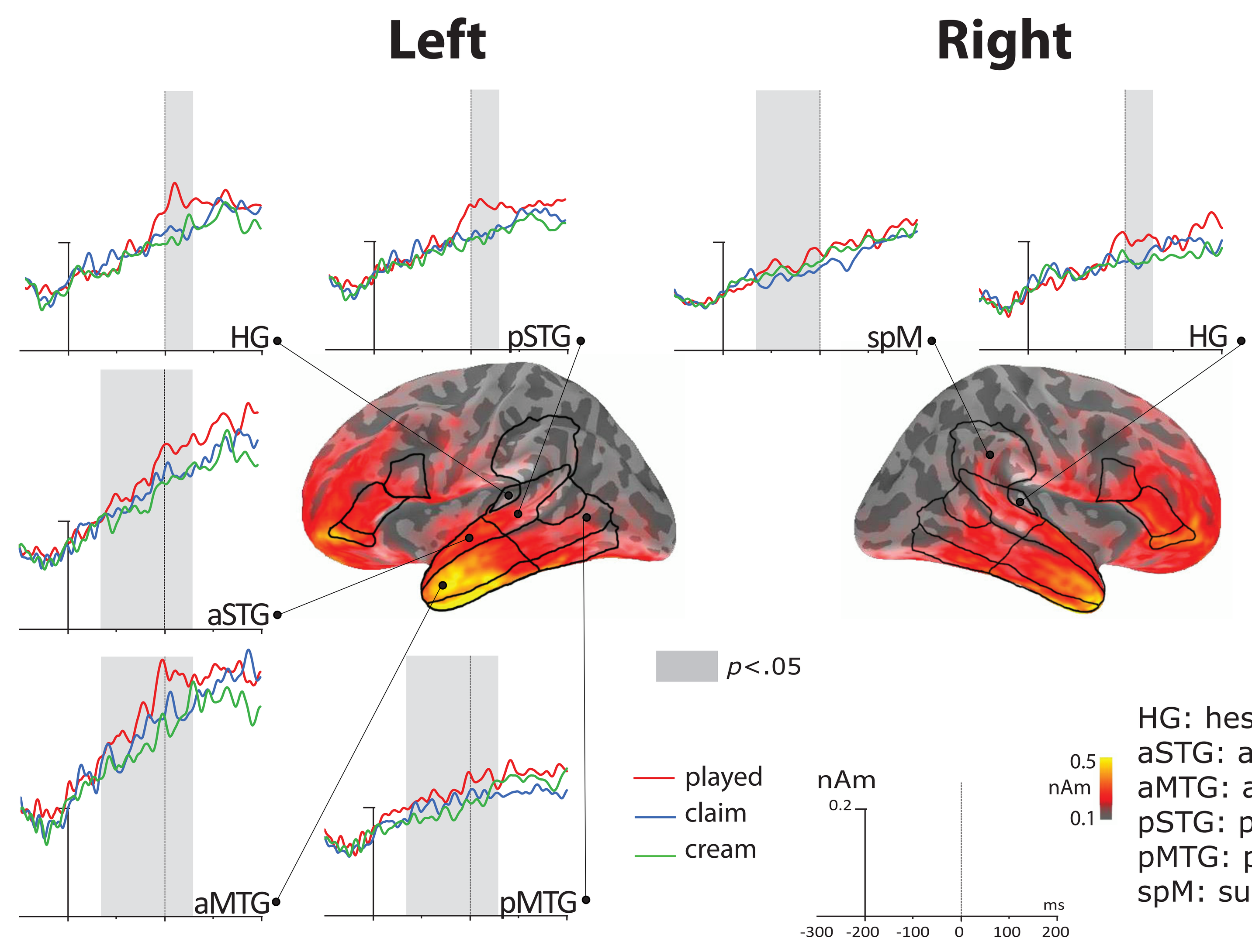


Sensor Level: Univariate Analysis (SPM)

Each sensor type was analysed separately with SPM5 by comparing activation patterns while correcting for multiple comparisons using Random Field Theory (extent $p<.05$ corrected, height $p<.01$) [6].



Source Level: Univariate Analysis (MNE)

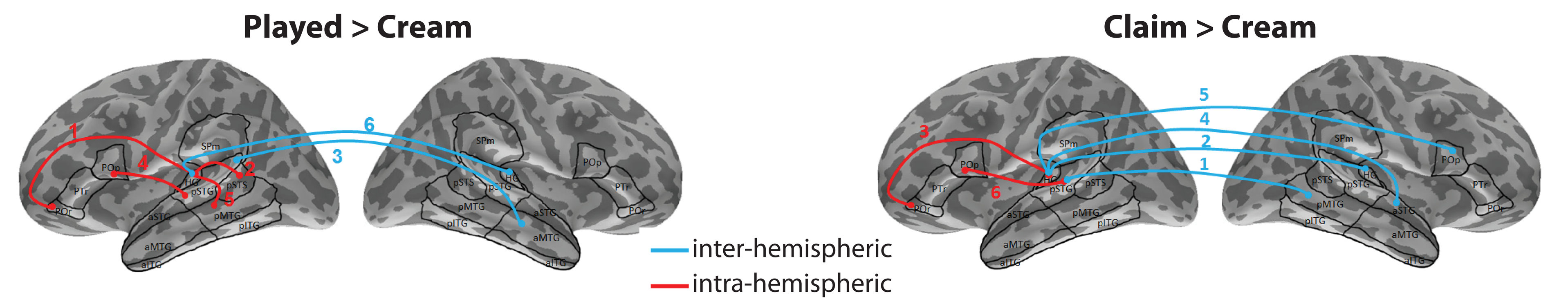


For each region of interest (FreeSurfer pre-defined; 12 per hemisphere) amplitude of the source estimates (MNE) was computed for 2 time windows: pre-IRP (-145 to 0 ms) and post-IRP (0 to +45 ms) and statistically evaluated with repeated measure ANOVAs (3 conditions: played, claim, cream).

HG: heschl's gyrus
aSTG: anterior superior temporal gyrus
aMTG: anterior middle temporal gyrus
pSTG: posterior superior temporal gyrus
pMTG: posterior middle temporal gyrus
spM: supra marginal

Source Level: Phase-Locking Values Analysis

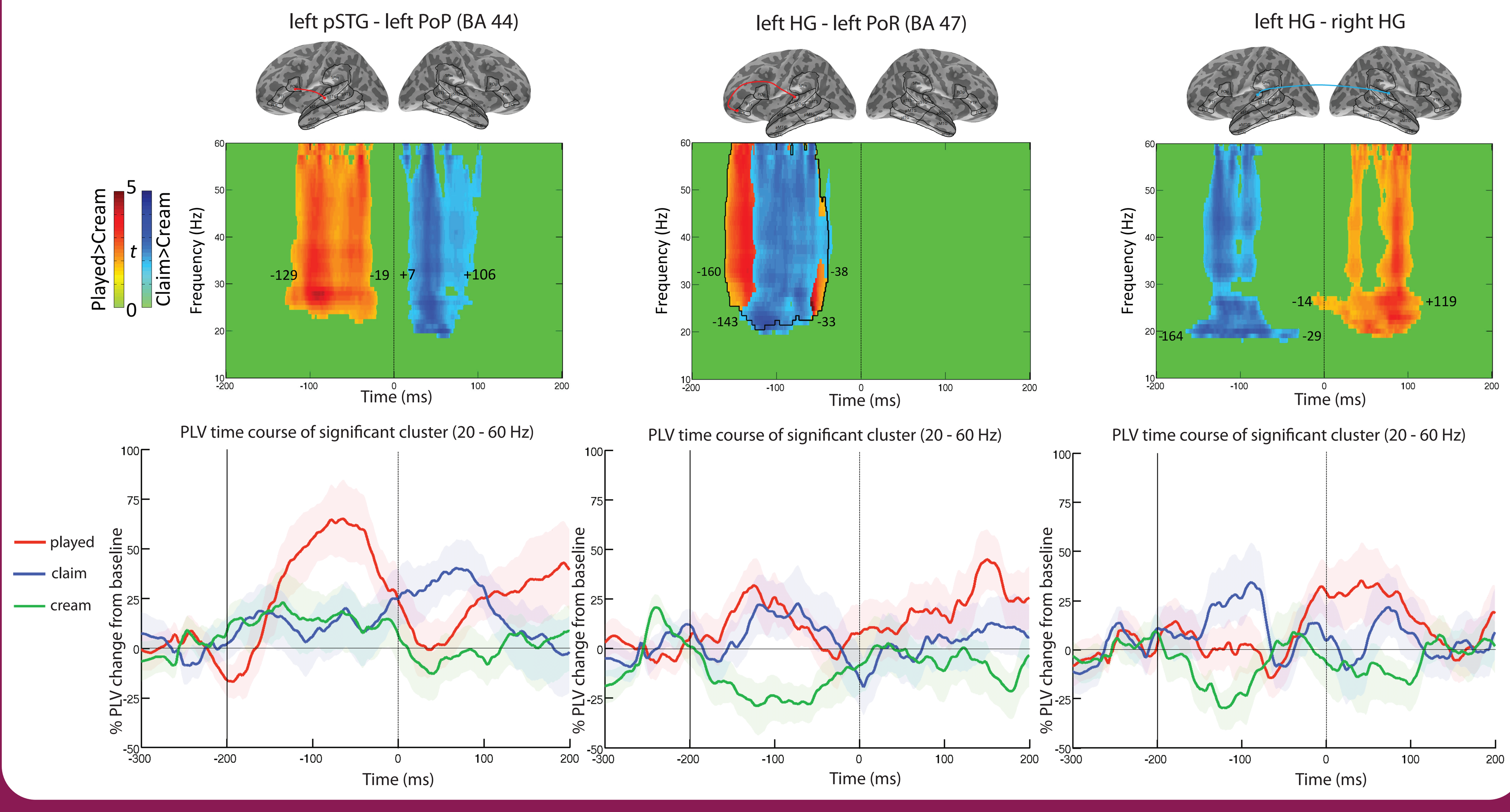
Cross-cortical synchrony [4] was analysed between HG and pSTG and other ROIs. Larger Phase Locking Values (PLVs) [3] reflect smaller trial-by-trial variance and therefore greater coupling between the phases of the signals. PLVs analysis was focused on the 10 to 60 Hz frequency bands and within the -200 to 200 ms time window. Cluster-level statistics were used to correct for multiple comparisons ($p<.05$).



		Cluster		frequency band (Hz)	p	max (Hz/ms/t)
Played > Cream						
Left HG- Left Pars Orbitalis (47)	1	-160	-38	22-60	0.003	26/-60/6.33
Left HG - Left pSTS	2	-151	-28	23-60	0.006	58/-58/4.75
Left pSTG -Right aMTG	3	-145	+40	19-60	0.008	31/-117/4.68
Left pSTG - Left Pars Opercularis (44)	4	-129	-19	23-60	0.02	29/-91/4.34
Left HG- Left pMTG	5	-67	+96	19-60	0.01	60/-37/3.02
Left HG -Right HG	6	-14	+119	20-60	0.04	24/+83/3.54

		Cluster		frequency band (Hz)	p	max (Hz/ms/t)
Claim > Cream						
Left pSTG – Right pMTG	1	-188	-14	23-60	0.01	60/-143/3.66
Left HG – Right HG	2	-164	-29	19-60	0.04	21/-93/3.54
Left HG – Left Pars Orbitalis (47)	3	-143	-33	21-60	0.02	23/-113/4.06
Left HG –Right aSTG	4	-142	-12	19-60	0.01	38/-122/4.00
Left HG –Right Pars Opercularis (44)	5	-45	+200	22-60	0.0004	61/+120/6.38
Left pSTG – Left Pars Opercularis (44)	6	+7	+106	20-60	0.04	60/+42/4.38

Time course analysis of the synchrony involving common ROIs between both networks.



Discussion

- Linguistic processing complexity led to increased neural responses around the IRP onset in all three type of sensors (Sensor Level).
- Amplitude of source activity increased for linguistically complex words related to simple words. This effect is distributed over temporal areas and is stronger in the left hemisphere (Source Level: univariate).
- Cortical oscillations revealed that linguistic complexity involved more left hemisphere synchronies in the gamma band than general complexity. The early left pSTG - left Pars Opercularis (BA 44) synchrony is triggered by the presence of specifically linguistic complexity (IRP) while synchrony with BA 47 (left HG - left Pars Orbitalis) is triggered by complexity common to linguistic and non-linguistic conditions (Source Level: PLVs).
- These differential patterns of functional connectivity, seen in these detailed real-time analyses, are consistent with emerging views about the processing roles of different fronto-temporal regions.

References

[1] Marslen-Wilson W & Tyler LK (2007). Philos Trans R Soc Lond B Biol Sci, 363: 917-921.
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Info

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