

EVIDENCE OF SYNTACTIC WORKING MEMORY USAGE IN MEG DATA

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Working memory is crucial to theories of language processing
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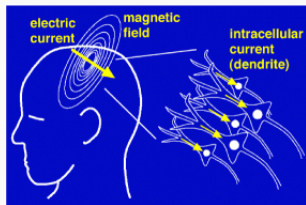
Reading times are low dimensionality and strongly affected by frequency effects.

We find a measure of memory load unaffected by frequency effects.

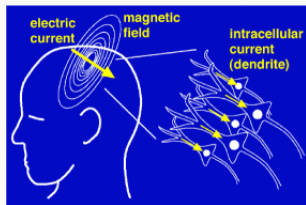
WHAT IS MEG?



WHAT IS MEG?



WHAT IS MEG?



102 locations

WHAT IS MEG?

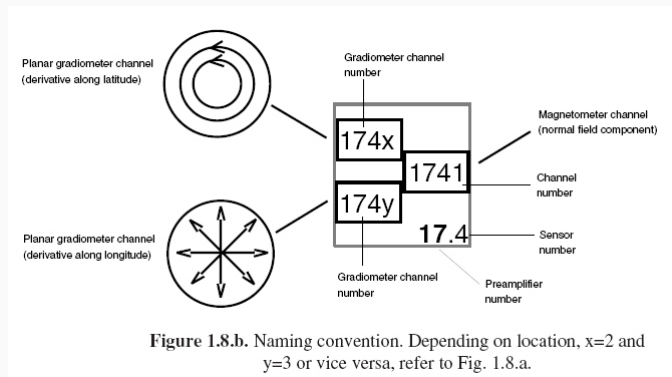
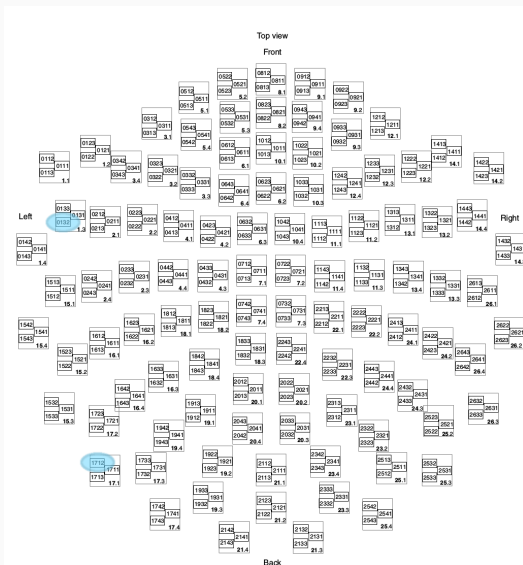
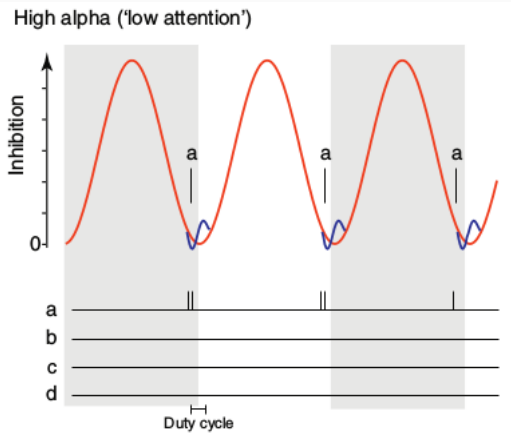


Figure 1.8.b. Naming convention. Depending on location, $x=2$ and $y=3$ or vice versa, refer to Fig. 1.8.a.

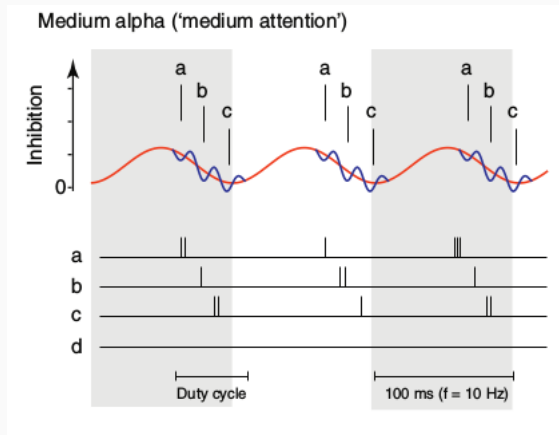
3 sensors per location

SENSORS OF INTEREST: 0132 & 1712





Jensen et al., (2012)



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Connectivity is neural communication

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This study measures connectivity with *spectral coherence*.

$$\text{coherence}(x, y) = \frac{E[S_{xy}]}{\sqrt{E[S_{xx}] \cdot E[S_{yy}]}}$$

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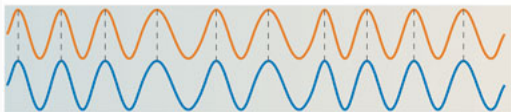
← cross-correlation
← autocorrelations

$$\text{coherence}(x, y) = \frac{E[S_{xy}]}{\sqrt{E[S_{xx}] \cdot E[S_{yy}]}}$$

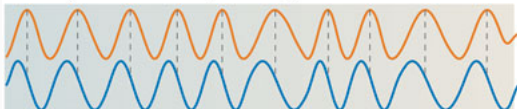
← cross-correlation
← autocorrelations

Amount of connectivity not caused by chance

Phase synchronization: phase lag = 0°



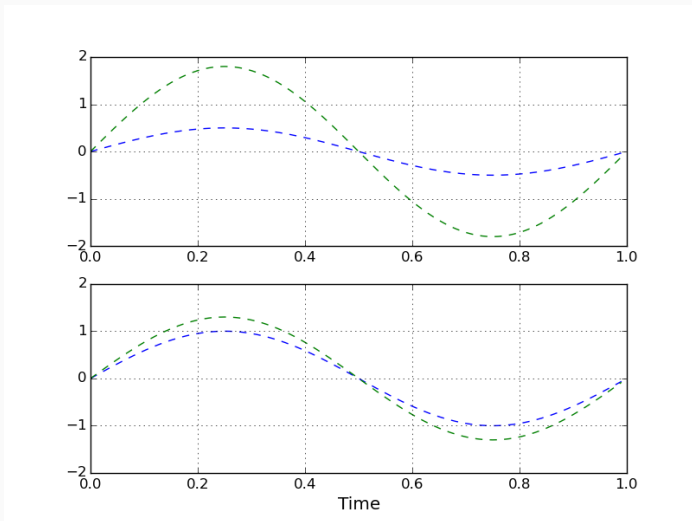
Phase synchronization: phase lag $\neq 0^\circ$



Nature Reviews | Neuroscience

Fell & Axmacher (2011)

SPECTRAL COHERENCE: POWER SIMILARITY



Collected 2 years ago at CMU

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3 subjects

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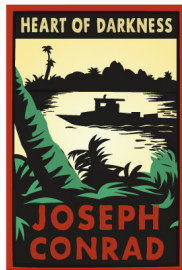
3 subjects

Heart of Darkness, ch. 2

12,342 words

80 (8 x 10) minutes

Synched with parallel audio recording
and forced alignment



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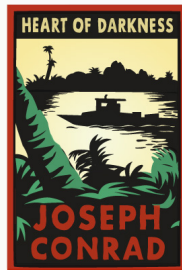
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306-channel Elekta Neuromag, CMU

Movement/noise correction: SSP, SSS, tSSS

Band-pass filtered 0.01–50 Hz

Downsampled to 125 Hz

Visually scanned for muscle artifacts; none found

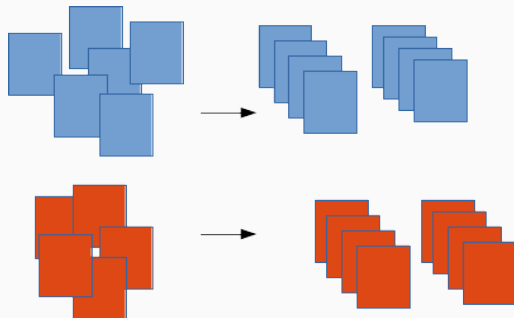
Remove words:

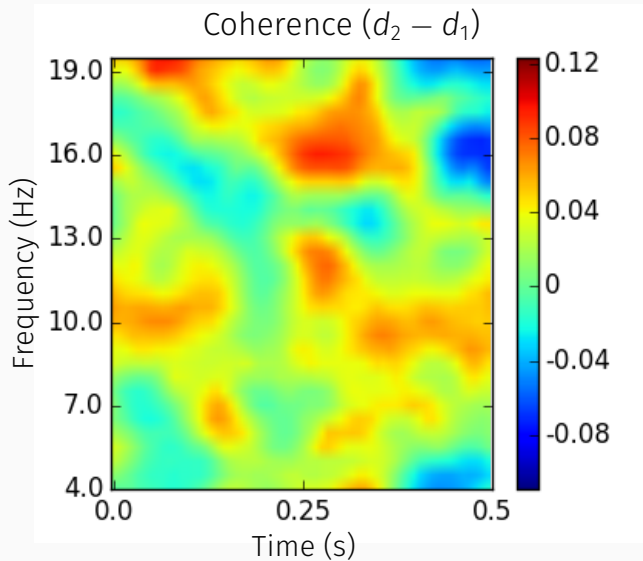
- in short or long sentences (<4 or >50 words)
- that follow a word at another depth
- that fail to parse

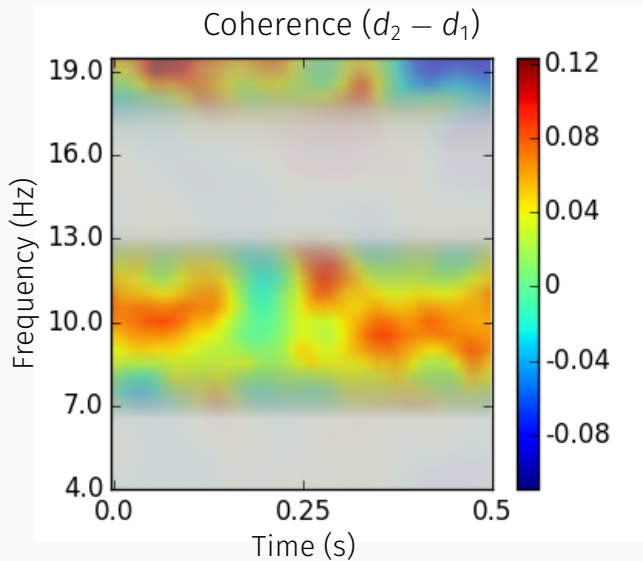
Partition data:

- Dev set: One third of corpus
- Test set: Two thirds of corpus

- Group by factor
- Compute coherence over subsets of 4 epochs







Sentence position

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Unigram, Bigram, Trigram: COCA logprobs

Sentence position

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PCFG surprisal: parser output

Factor	p-value
Unigram	0.941
Bigram	0.257
Trigram	0.073
PCFG Surprisal	0.482
Sentence Position	0.031
Depth	0.005

Depth 1 (40 items)

Depth 2 (1118 items)

Factor	p-value
Unigram	0.6480
Bigram	0.7762
Trigram	0.0264
PCFG Surprisal	0.3295
Sentence Position	0.4628
Depth	0.00002

Depth 1 (86 items)

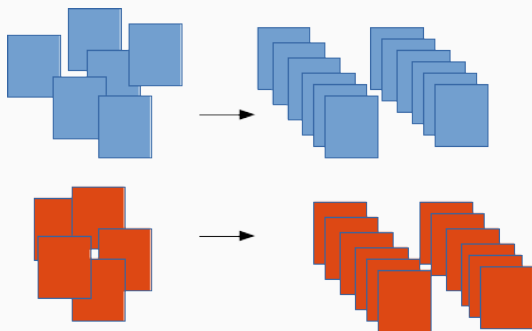
Depth 2 (2142 items)

Factor	p-value
Unigram	0.6480
Bigram	0.7762
Trigram	0.0264
PCFG Surprisal	0.3295
Sentence Position	0.4628
Depth	0.00002

Bonferroni correction removes trigrams, but ...

COMPUTE COHERENCE: INCREASED RESOLUTION

- Group by factor
- Compute coherence over subsets of 6 epochs



TEST RESULTS: INCREASED RESOLUTION

Factor	p-value
Trigram	0.3817
Depth	0.0046

Depth 1 (57 items)

Depth 2 (1428 items)

- Memory load is reflected in MEG connectivity
- Common confounds do not pose a problem in MEG α connectivity

- Can we see integration cost?
- Can we see storage cost?
- Can we see similarity interference?
- Can we see sentence processing operations?

Thanks to:

- The anonymous reviewers
- Roberto Zamparelli, University of Trento
- National Science Foundation (DGE-1343012)
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- National Institutes of Health CRCNS (5R01HD075328-02)

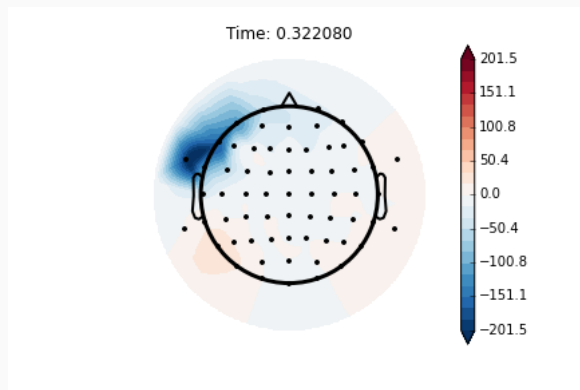
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- Coherence decreases between d_2 and d_3

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Suggests finding due to increased synchrony
- Coherence decreases between d_2 and d_3
- Likely due to observed power decrease in left anterior

EEG $d_3 - d_2$ (6 subjects)



Factor	Coef	p-value
Unigram	$5.1 \cdot 10^{-5}$	0.941
Bigram	$5.6 \cdot 10^{-4}$	0.257
Trigram	$4.3 \cdot 10^{-4}$	0.073
PCFG Surprisal	$2.8 \cdot 10^{-4}$	0.482
Sentence Position	$-5.1 \cdot 10^{-4}$	0.031
Depth	$3.6 \cdot 10^{-2}$	0.005

Depth 1 (40 items)

Depth 2 (1118 items)

Factor	Coef	p-value
Unigram	$-2.2 \cdot 10^{-4}$	0.6480
Bigram	$-9.8 \cdot 10^{-5}$	0.7762
Trigram	$3.7 \cdot 10^{-4}$	0.0264
PCFG Surprisal	$2.9 \cdot 10^{-4}$	0.3295
Sentence Position	$1.3 \cdot 10^{-4}$	0.4628
Depth	$4.6 \cdot 10^{-2}$	0.00002

Depth 1 (86 items)

Depth 2 (2142 items)

TEST RESULTS: INCREASED RESOLUTION

Factor	Coef	p-value
Trigram	$1.6 \cdot 10^{-4}$	0.3817
Depth	$3.2 \cdot 10^{-2}$	0.0046

Depth 1 (57 items)

Depth 2 (1428 items)