Neural correlates of action words

Preliminary results of a magnetoencephalographic (MEG) study

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Colloquium 21.06.2012

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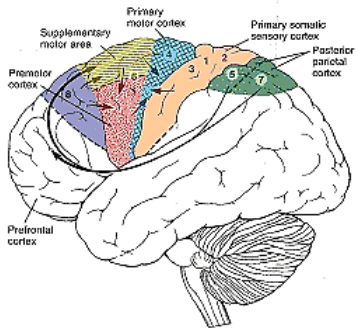
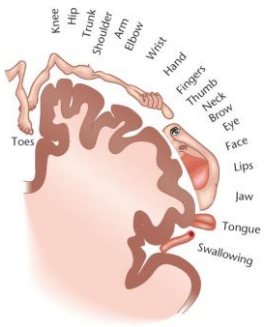
Embodied cognition

Language comprehension depends on the involvement of sensory and motor brain areas (Barsalou, 2008)





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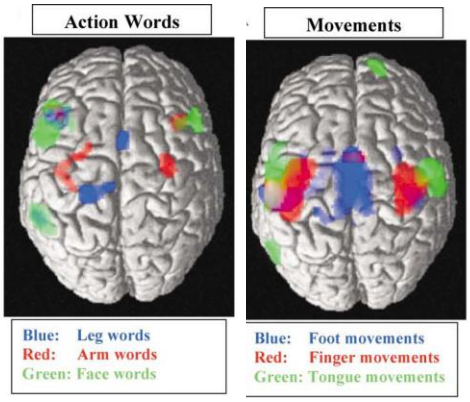
Somatotopic semantic activation along the motor strip during action-related word processing



Hauk et al., 2004

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MEG (magnetoencephalography)

- Direct and non invasive measure of the cerebral activity
- **High temporal resolution (< 1 ms)**
- Good spatial resolution
- Detection of cerebral networks
- **Power detection of specific brain frequencies**
- **Detection of sources of activation**

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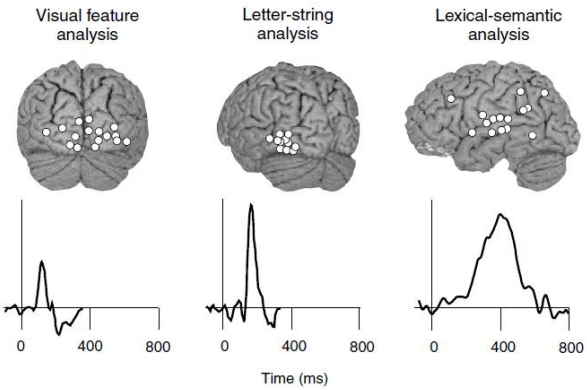
The MEG approach: cortical dynamics of silent reading



Salmelin et al., 2007

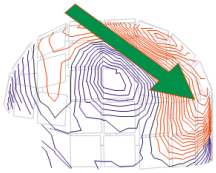
Our MEG study

- activation of movement related sources while reading action words
- brain oscillations during processing of action words and relative distribution on the cortex

Two analyses of the magnetic signal

Magnetic field

Dipole source of magnetic fields



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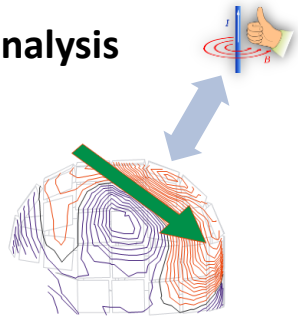
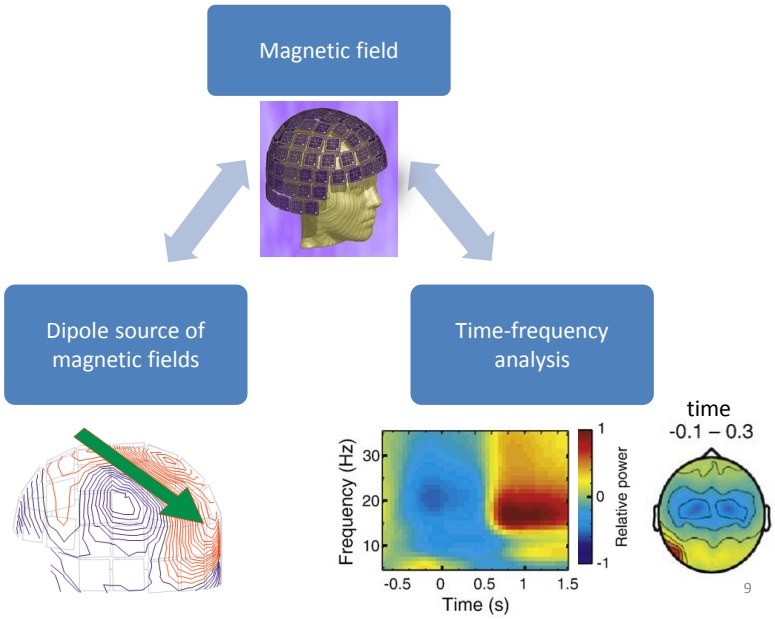
Dipole source analysis



Dipole:

- represents the center of the active cortical area
- x-, y-, z- coordinates → location in the brain
- orientation
- magnitude (strength)
- time course of activation

Two analyses of the magnetic signal



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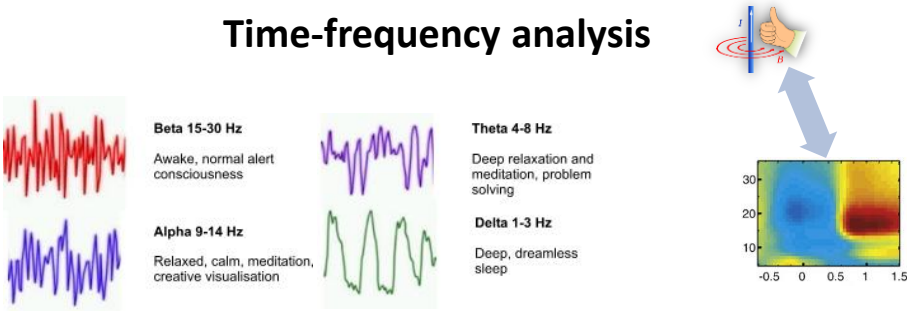
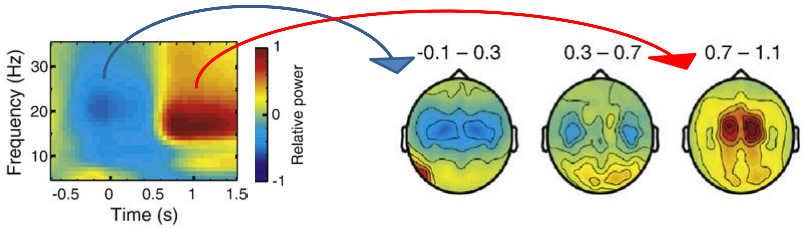
Time-frequency analysis



Beta rhythm → *motoric preparation/execution:*



Koelewijn et al., 2008

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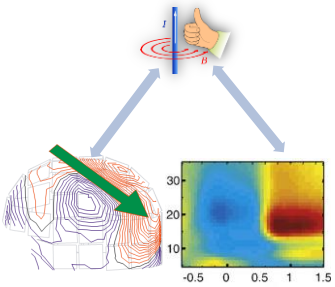
Hypotheses



1. Neuronal sources of hand/foot movement revealed by dipolar source modelling can (partially) explain brain activity during hand/foot action verb reading (somatotopically)

2. Stronger motor cortex β-desynchronization (15-30 Hz) during processing of body-related action verbs (somatotopically)

Methods: Subjects

- 15 (8 females) university students, age 22,3 (SD=2)
- right-handed (average laterality quotient of 84 - Edinburgh Inventory of Oldfield) and right-footed (laterality Preference Inventary - Ehrenstein und Arnold-Schulz-Gahmen, 1997)
- monolingual and German native speaker
- normal or corrected to normal vision
- no psychiatric disease or neurological disorder
- MEG exclusion criteria

Methods: Material

ACTION verbs (infinitives) → 3 conditions:

1. Hands (N = 48*2)
2. Feet (N = 48*2)
3. Non-body (N = 48*2)

Selection based on a rating study on 30 German (17 F) native speakers

Matched on

- length (2 syllabs, on average 7 letters)
- frequency (Leipzig Database, http://corpora.informatik.uni-leipzig.de)
- imageability
- familiarity

rating study on other 30 German native speakers

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Methods: Material

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Matched on

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- imageability
- familiarity

4. filler verbs (18*2)
5. pseudowords (18*2)

(20% of all stimuli) → lexical decision task

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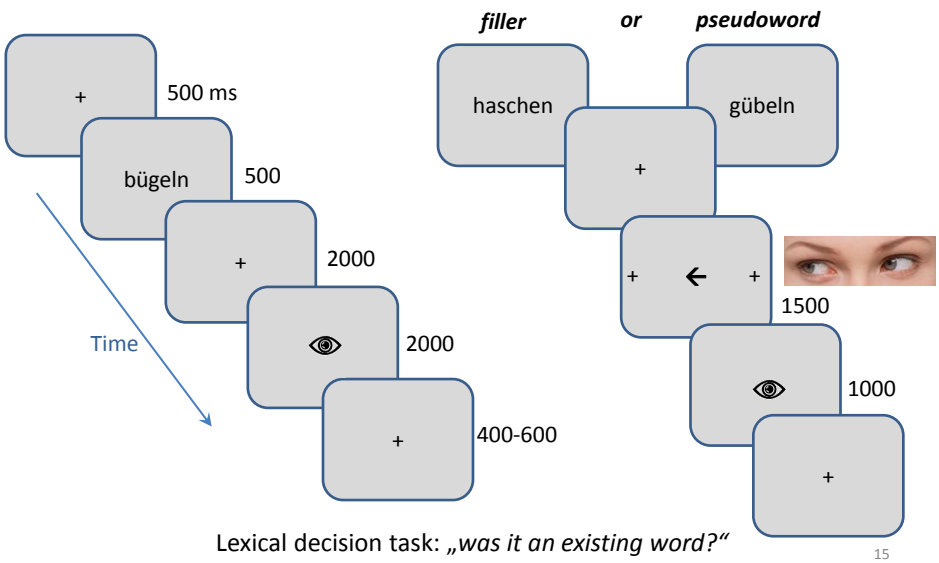
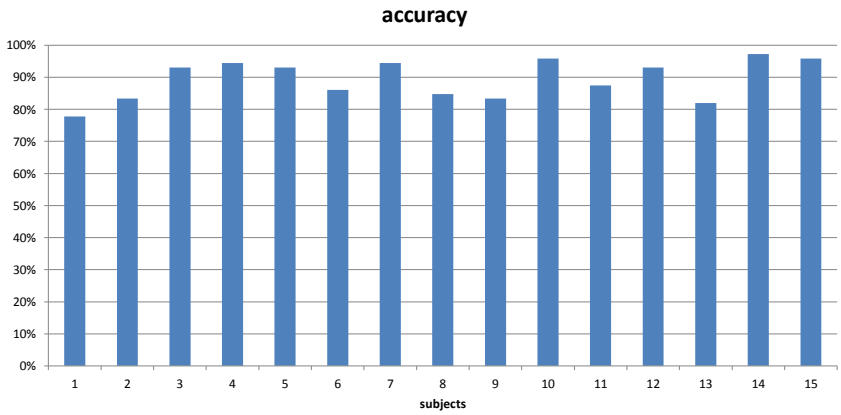
Verbal task



Lexical decision task: *„was it an existing word?“*

Behavioural results



Average = 89% (SD=6)

Movement tasks

1. alternating hand movement
2. alternating foot movement

Movement details:

- voluntary
- self-paced
- brisk extension
- every 2 seconds for 5 minutes

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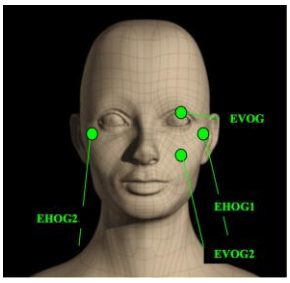
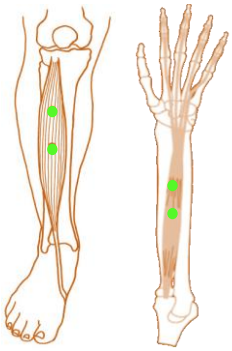
MEG setup

EOG for eye movements



EOG = electroculogram
EVOG → vertical EOG
EHOG → horizontal EOG

EMG for arms/legs movements

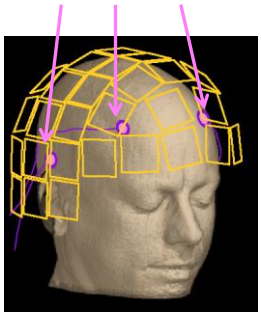


EMG = electromiogram

M. tibialis anterior

M. extensor digitorum communis

Coils for head movements



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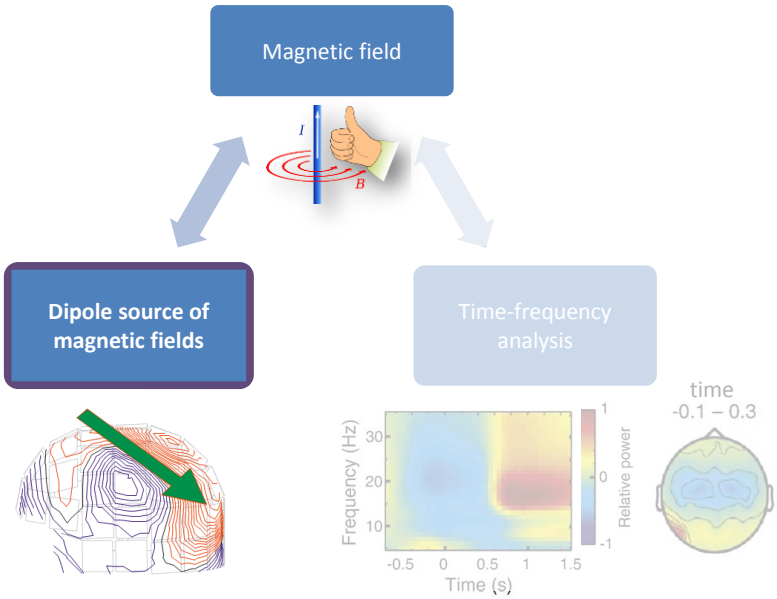

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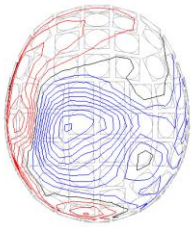
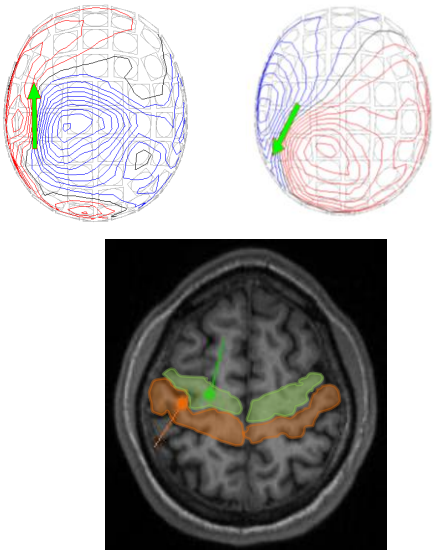
Dipole approach



Movement paradigm

- Movements of hand and foot induce neuromagnetic fields (Deecke et al., 1982)

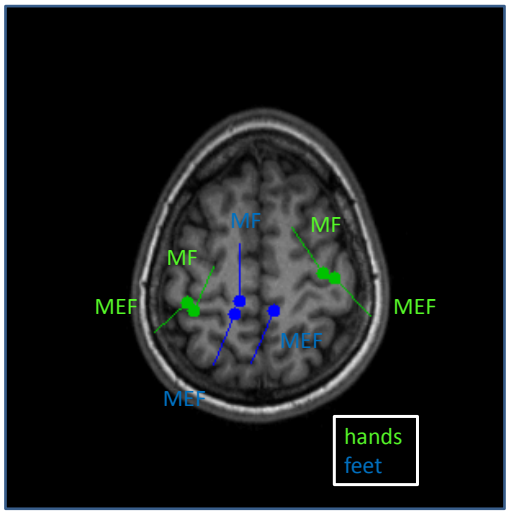
Dipole approach



Movement paradigm

- Movements of hand and foot induce neuromagnetic fields (Deecke et al., 1982)
- motor field (MF) = preparatory changes in primary motor cortex (Kristeva-Feige et al., 1994)
- movement-evoked field (MEF) = sensory feedback after movement onset (Cheyne and Weinberg, 1989)

Results: Dipole approach (movement paradigm)

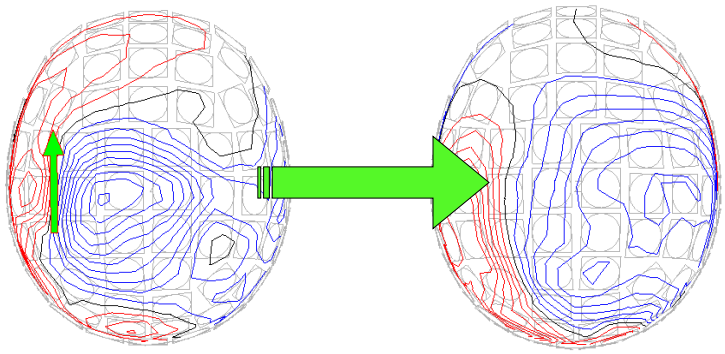


- Each movement characterized by 2 dipoles (total 8)

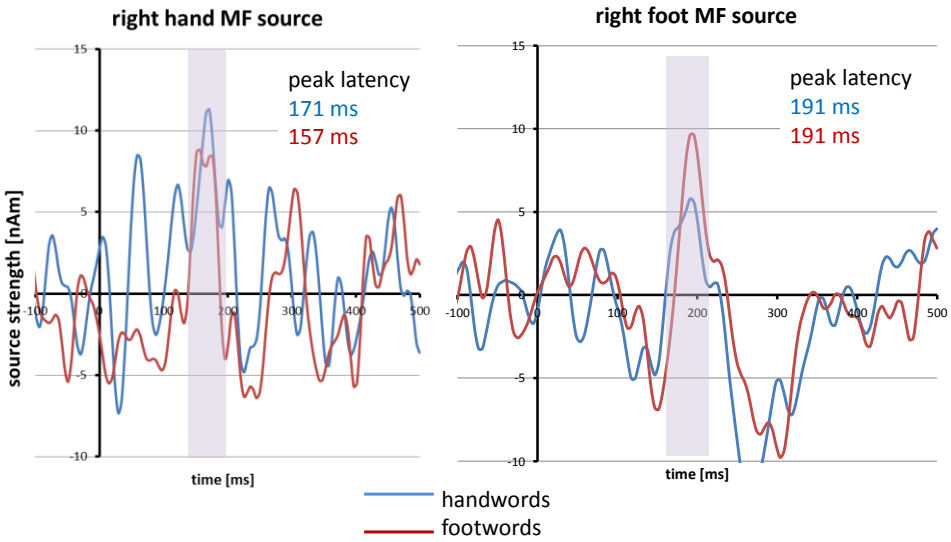
Source transfer to the word paradigm

Brain activity during hand movement

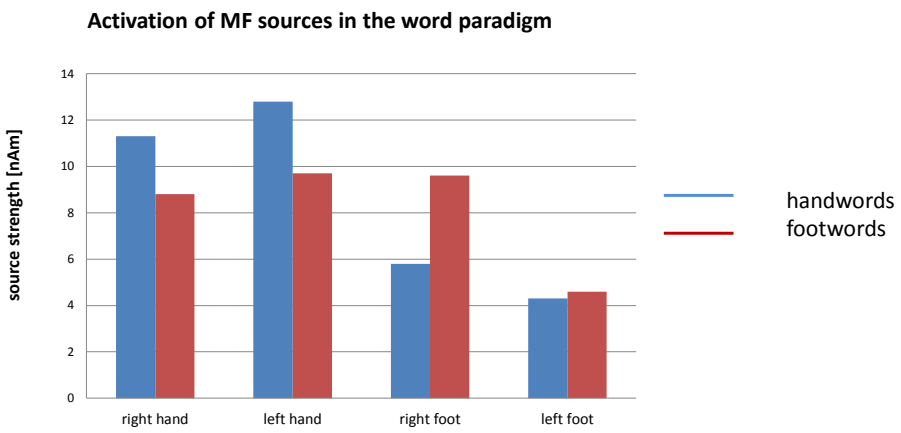
Brain activity while reading hand words



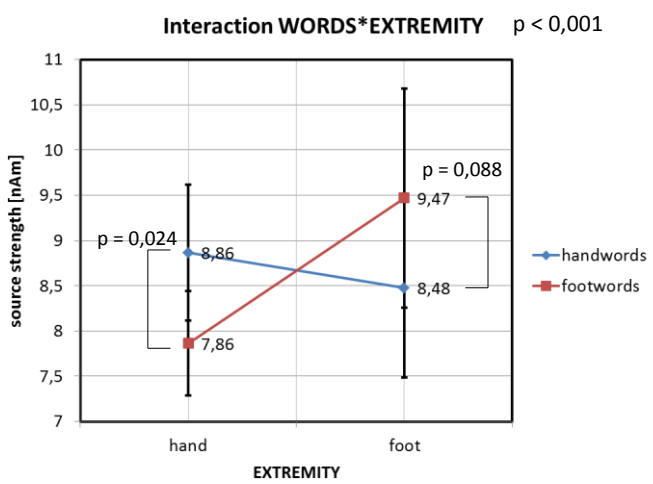
Results: Dipole approach (word paradigm)



Results: single subject

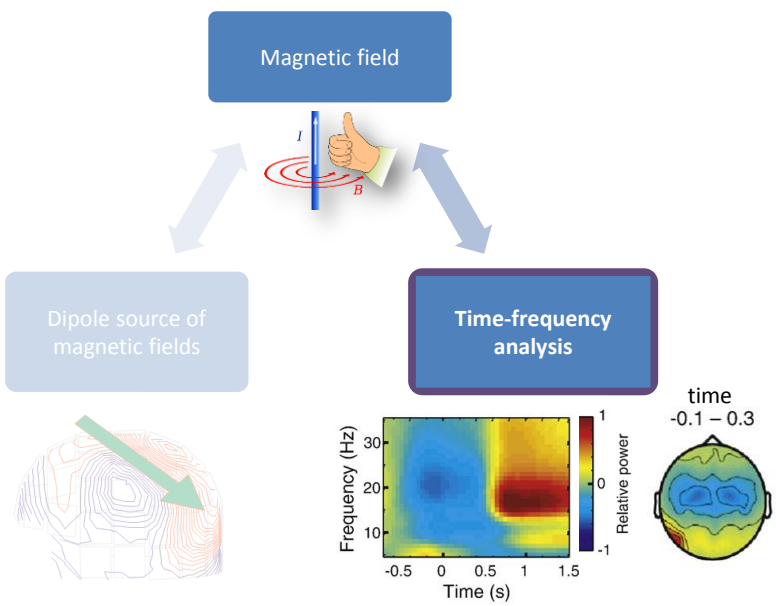


Group results



Dipole Source Modelling: Summary

- early activation of movement-related sources during processing of action verbs (mean peak latency = 195/193 ms)
- significantly higher activation in the effector-related verb condition (p < 0,001)
- next goal: laterality



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Time-frequency analysis

Matlab software toolbox Fieldtrip

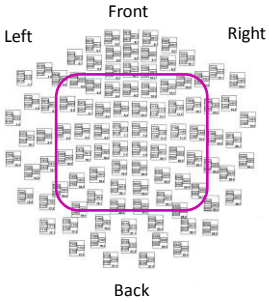
Preprocessing steps:

- artefact rejection: blinks, movements
- independent component analysis (for electrocardiogram artefacts)

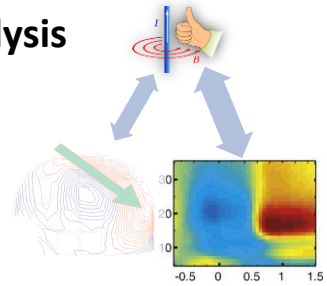
→ Trial: N=255, from -0,5 to 1 sec

Statistics

- on 13 subjects
- 27 sensory-motor channels
- Hand vs. Non-body



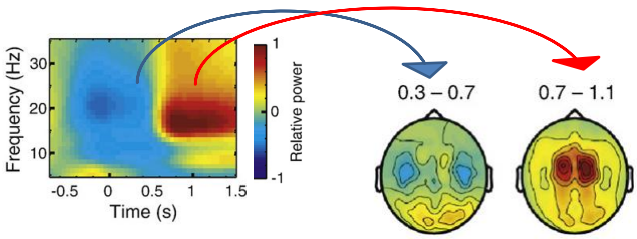
Time-frequency analysis



<u>Beta rhythm → *motoric preparation/execution:*</u>

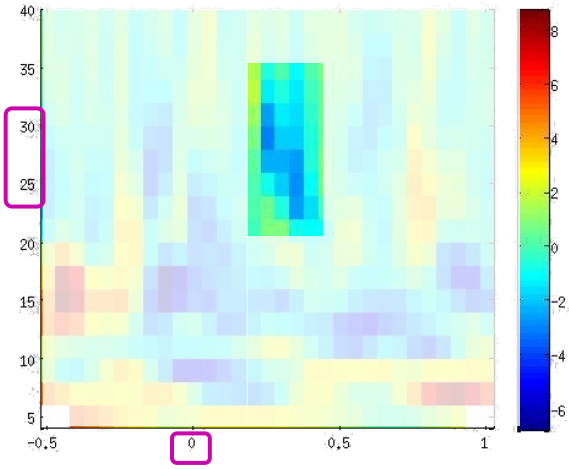
Beta 15-30 Hz

Awake, normal alert consciousness



Koelewijn et al., 2008

Results: Hand vs. Non-body beta desynchronization



Word onset

P < 0.05

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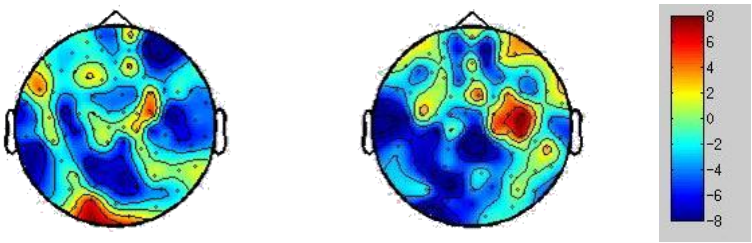
Results: beta desynchronization

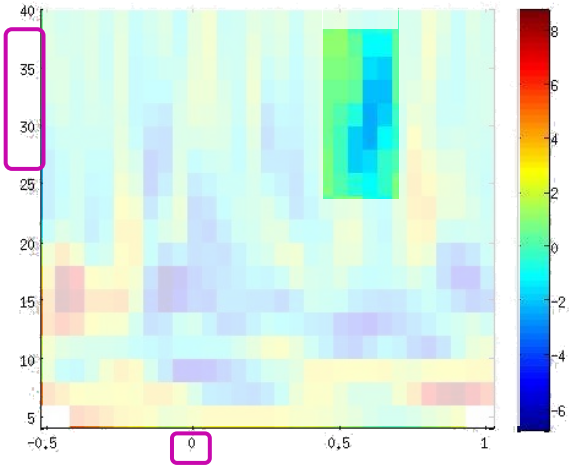
Frequency 25 -30



Time 0.30 - 0.32 0.38 - 0.4

32

Results: beta desynchronization

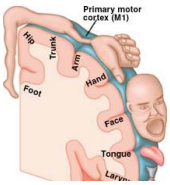


Word onset

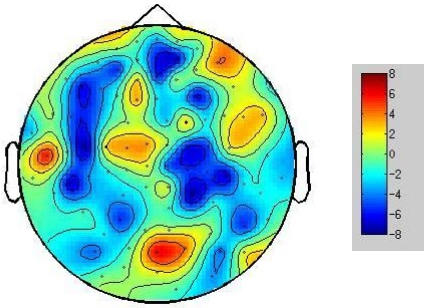
P < 0.05

33

Results: beta desynchronization



Frequency 25 - 35



Time 0.59 - 0.61

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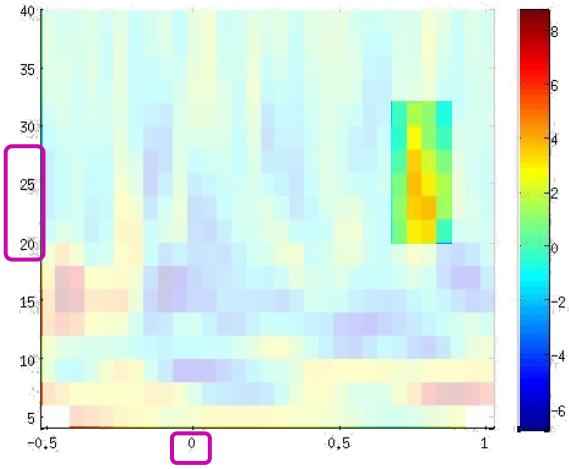
Results: beta rebound

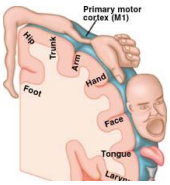


Word onset

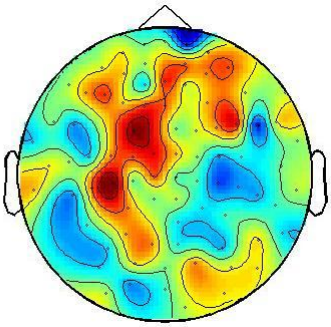
P < 0.05

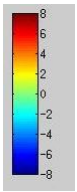
35

Results: beta rebound



Frequency 20 - 28





Time 0.7 - 0.8

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Summary time-frequency analysis

Hands vs. non-body verbs contrast:

- Beta desynchronization beginns around 300 ms post-word onset
- Beta rebound (synchronization) around 750 ms post-word onset
- Plausible ‚hand' brain region

Next goal:

- Source localization of oscillations