Neural correlates of action words
Preliminary results of a magnetoencephalographic (MEG) study

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Embodied cognition

Language comprehension depends on the involvement of sensory and motor brain areas (Barsalou, 2008)
Somatotopic semantic activation along the motor strip during action-related word processing

Hauk et al., 2004

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
The MEG approach:
cortical dynamics of silent reading

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

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

Magnetic field

Dipole source of magnetic fields

Time-frequency analysis

Time-frequency analysis

Beta rhythm \(\rightarrow\) motoric preparation/execution:

Koelewijn et al., 2008
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 Inventory - 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)

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

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

4. filler verbs (18*2)
5. pseudowords (18*2) (20% of all stimuli) → lexical decision task
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 = electroculogram  
EVOG  →  vertical EOG  
EHOG  →  horizontal EOG  

EMG = electromiogram  

M. tibialis anterior  
M. extensor digitorum communis
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)

<table>
<thead>
<tr>
<th></th>
<th>right hand MF source</th>
<th>right foot MF source</th>
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<tbody>
<tr>
<td>peak latency</td>
<td>171 ms</td>
<td>191 ms</td>
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<tr>
<td></td>
<td>157 ms</td>
<td>191 ms</td>
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</tbody>
</table>

![Graph showing source strength over time](image)

- **Right hand MF source**
  - Peak latency: 171 ms, 157 ms

- **Right foot MF source**
  - Peak latency: 191 ms
Results: single subject

Activation of MF sources in the word paradigm

Group results

Interaction WORDS*EXTREMITY  p < 0.001
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
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

Beta rhythm \(\rightarrow\) motoric preparation/execution:

Beta 15-30 Hz
Awake, normal alert consciousness

Koelewijn et al., 2008
Results: Hand vs. Non-body beta desynchronization

![Graph showing beta desynchronization results.]

Time 0.30 - 0.32 0.38 - 0.4

Results: beta desynchronization

Frequency 25 - 30

![Graph showing beta desynchronization results.]

Time 0.30 - 0.32 0.38 - 0.4
Results: beta desynchronization

Word onset

P < 0.05

Frequency 25 - 35

Time 0.59 - 0.61
Results: beta rebound

Frequency 20 - 28

Time 0.7 - 0.8

P < 0.05
Summary time-frequency analysis

Hands vs. non-body verbs contrast:

• Beta desynchronization begins 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