Neural activation to actions performed with hands and legs
Real movements versus action verb reading

Hannah Weissler
SFB991 Project B03
PI: Katja Biermann-Ruben & Alfons Schnitzler
Collaborators: Valentina Niccolai, Anne Klepp
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Institute of Clinical Neuroscience and Medical Psychology
Introduction
How is knowledge organized in the brain?

- amodal symbols (Fodor, 2001)
- multimodal representation (Barsalou, 2008)

internal simulation of experiences acquired during perception, action, and introspection associated with an object (Barsalou, 2008)

Cognition is grounded
Action concepts in the brain

- representation of action concepts in the brain involve the sensorimotor cortex (Barsalou, 2008)
- distributed neuronal networks (Pulvermüller, 2005)

Penfield & Rasmussen, 1950
Neurophysiological evidence

- reading of action verbs (Hauk et al., 2004)
- listening to action-related sentences (Tettamanti et al., 2005)
The mirror neuron system

in F5 (Broca’s area), inferior parietal lobule, and in premotor cortex

neurons that are active:

• **execution** of a movement

• **observation** of another person execute a movement (Rizzolatti et al., 2001)

• **hearing** a sound due to an action (Kohler et al., 2002)

• when **reading action words** (Hauk et al., 2004) and **action phrases** (Aziz-Zadeh et al., 2006)

  possible role in language development
  
  (Rizzolatti & Arbib, 1998; Arbib, 2005; Sterelny, 2012)
MEG (magnetoencephalography)

- non invasive measure of the cerebral activity
- high temporal resolution (< 1 ms)
- good spatial resolution (cm)
- detection of sources of activation
Dipole source analysis

Dipole:

• represents the center of the active cortical area

• $x$, $y$, $z$-coordinates $\rightarrow$ location in the brain

• orientation

• magnitude (strength)

• time course of activation
Aim of the study

1. Are neuronal sources of hand/foot movement active during silent reading of hand/foot action verbs?

2. Somatotopical activation
Methods
Methods: Subjects

- 15 (8 females) university students, age 22 (SD=2)
- right-handed: Edinburgh Inventory (Oldfield, 1971)
- right-footed: Laterality Preference Inventory (Ehrenstein & Arnold Schulz-Gahmen, 1997)
- monolingual and German native speaker
- no linguists
Methods: Material

verbs (infinitives)

1. hand verbs (n = 48*2)
2. foot verbs (n = 48*2)
3. nonbody verbs (n = 48*2)

based on body part rating study with 30 participants
Verb reading task

500

+ bügeln

2000

+ 2000

Time (ms)
Verb reading task

lexical decision task: *filler* or *pseudo verb*

- zeigen
- knossen

Time (ms):
- 500
- 1500
- 1000
Movement tasks

1. alternating hand movement
2. alternating foot movement

Movement details:

- self-paced
- brisk extension
- every 2 seconds for 5 minutes
MEG setup

EOG = electrooculogram
EVOG → vertical EOG
EHOG → horizontal EOG

EMG for hands/feet movements

EOG for eye movements

EMG = electromyogram
M. tibialis anterior
M. extensor digitorum communis

Introduction
Methods
Results
Discussion
Movement paradigm

- Movements of hand and foot induce characteristic neuromagnetic fields

- **motor field** (MF) = preparatory changes in primary motor cortex

- **movement-evoked field** (MEF) = sensory feedback after movement onset

(Kristeva-Feige et al., 1994; modified)
Source transfer to the word paradigm

Brain activity during hand movement

Brain activity while reading hand verbs

Neuronal sources of hand/foot movement revealed by dipole source modelling are active during hand/foot action verb reading (somatotopically)
Results
Movement-related sources

[Image of brain scan with markers labeled MF and MEF, and a graph showing EMG onset and 4 nAm at 100 ms]
MF source activation in the verb conditions

right hand

-2 0 2 4 6
nAm
ms
word onset

hand verbs
foot verbs
MF source activation in the verb conditions

left hand

left foot

hand verbs
foot verbs

Introduction  Methods  Results  Discussion  

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Statistics

interaction words x extremity  $p < 0.001$

$p = 0.024$

$p = 0.088$

hand MF  foot MF

hand verbs  foot verbs
Discussion
1. Are neuronal sources of hand/foot movement revealed by dipole source modelling also active during hand/foot action verb reading?

   *Activation of motor field sources within 200 ms of action verb processing*

2. Somatotopical activation of movement-related sources

   *Significantly higher activation of hand MF source in hand verb condition (p = 0.024); strong tendency of higher activation of foot MF source in foot verb condition (p = 0.088)*
Discussion

activation of motor field sources within
the first 200 ms of action verb processing

crucial for **semantic processing** (Pulvermüller et al., 2009)

possible link between **mirror neuron system** and **language**
What is new in our study?

• preliminary body part rating study: in addition to hand, foot and nonbody verb category also face/mouth and whole body as possible answers
• EMG recordings assured that no movement of arm and leg muscles occurred during action verb reading
• MEG: distinguish between several early motor-related activations (MF and MEF)

Outlook

• nonbody verb condition
• prefixed verbs with motor stem → motor activation?
Thank you for your attention!