

**To move or not to move –
neural correlates in the Parkinsonian and healthy motor system**

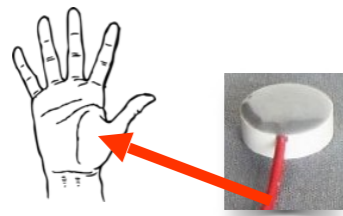
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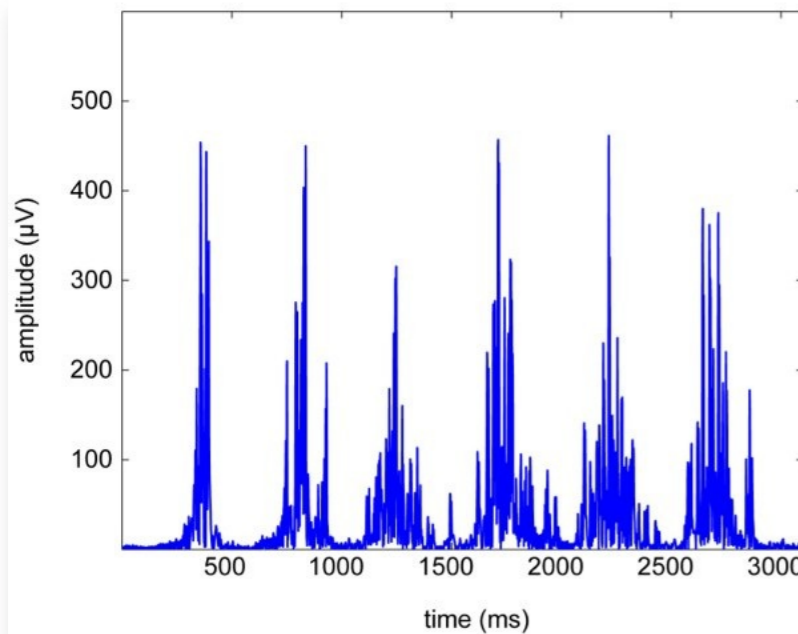
Can you do a movement...
...without doing it?



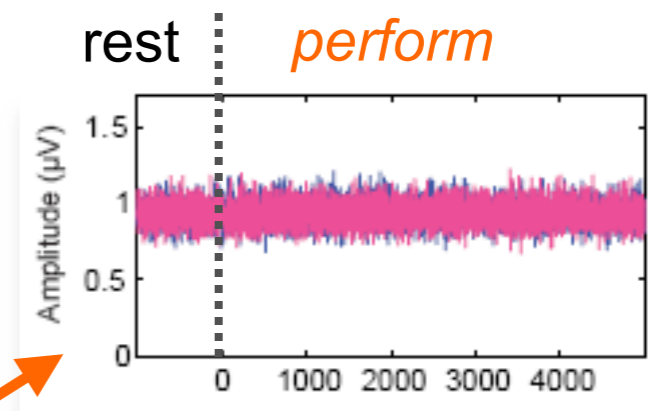
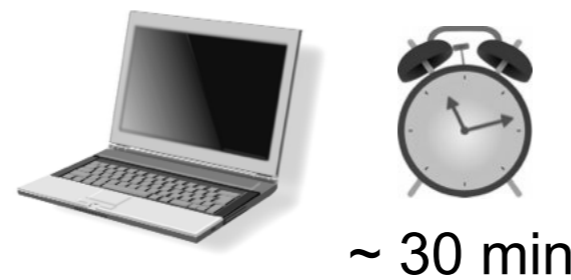
abductor pollicis brevis

“Perform a weak movement with your thumb.
Now **minimize this movement** even further
and make it **as small as possible.**”

normal thumb movement



EMG neurofeedback

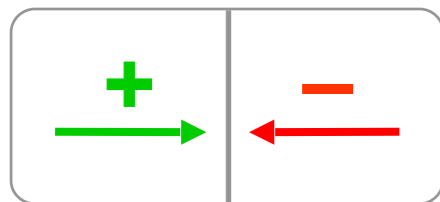


quasi-movements:
“**volitional movements with zero muscle output**”
undetectable by objective measures of muscle activity (e.g., EMG)

Hohlefeld et al. (NeuroReport, 2011); Hohlefeld et al. (Brain Res, 2011);
Hohlefeld (Free University, 2011); Nikulin*, Hohlefeld* et al. (Neuropsychologia, 2008)

movement performance:

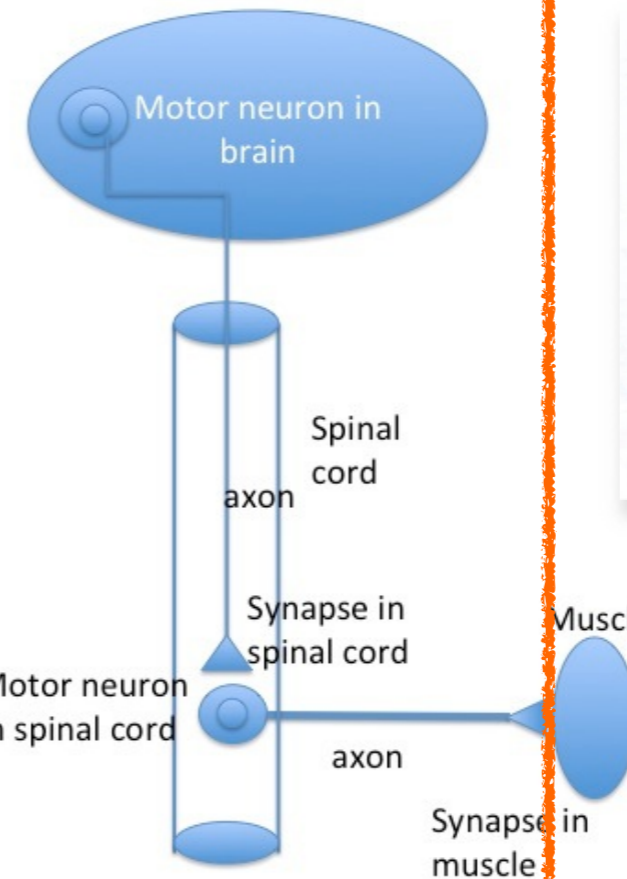
sequence of **neural activations**,
 related to carrying out a **motor intention**,
 culminating in **muscle contraction**



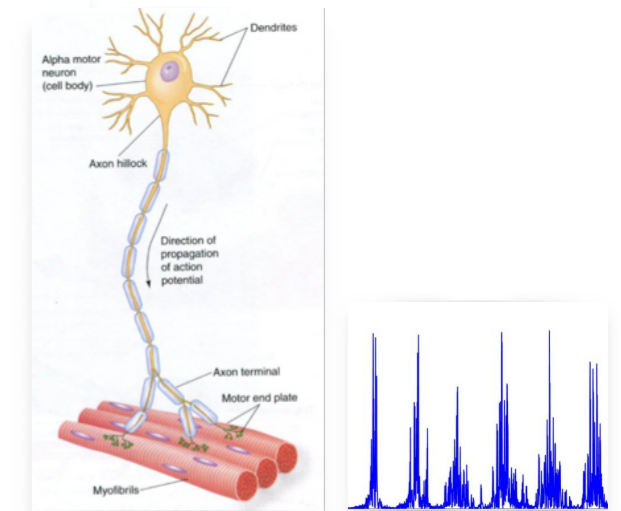
equilibrium
 “**meta-stable**”

either/and:
gas too weak
break too strong

covert stages



overt movement

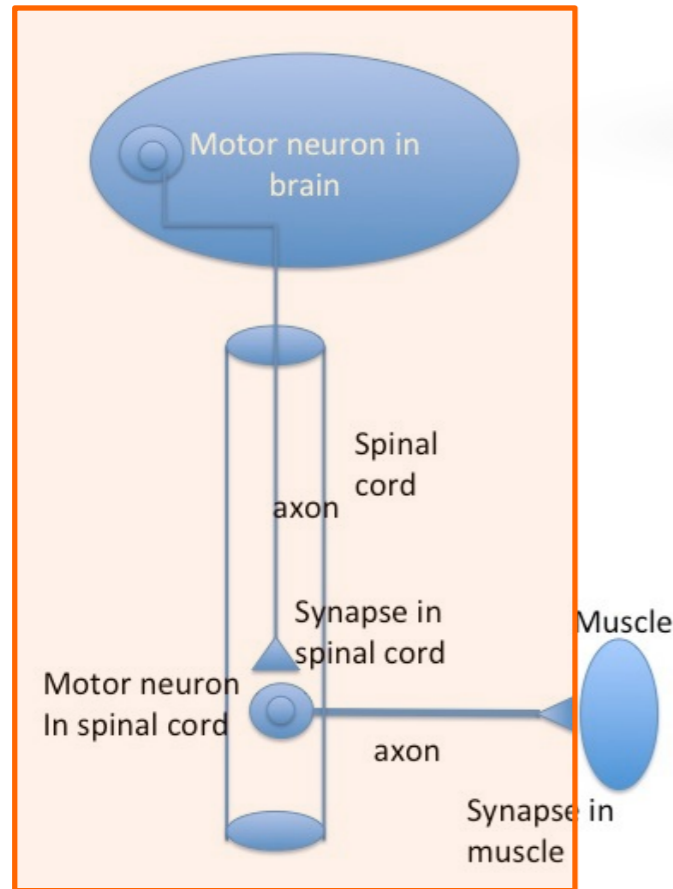


quasi-movements:
volitional movements with zero muscle output*

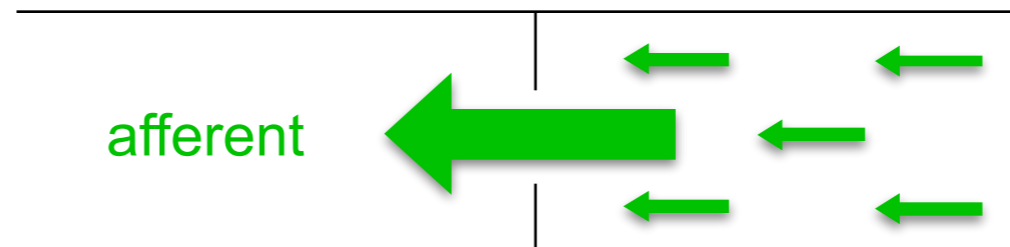
*as determined by objective measures

Hohlefeld et al., NeuroReport 2011; Hohlefeld et al., Brain Res 2011;
Hohlefeld FU 2011; Nikulin*, Hohlefeld* et al., Neuropsychologia 2008

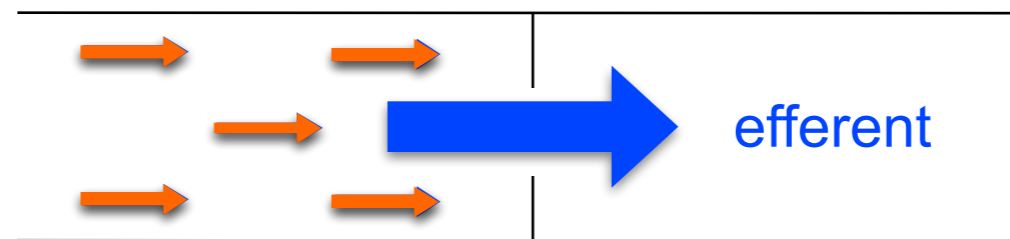
covert



sensory threshold



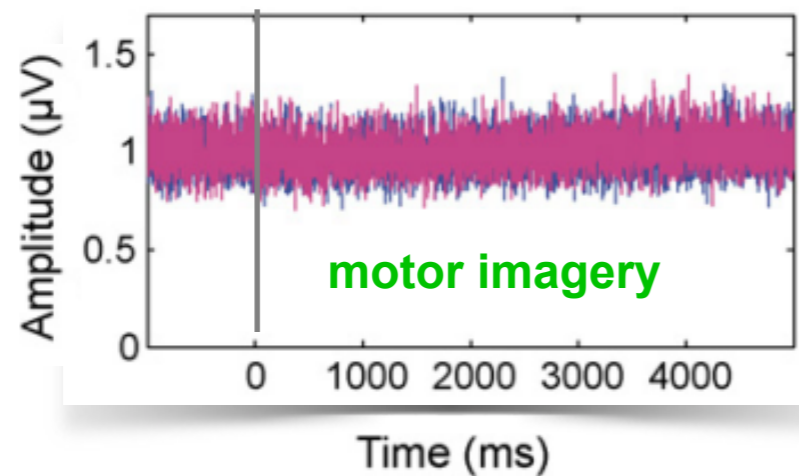
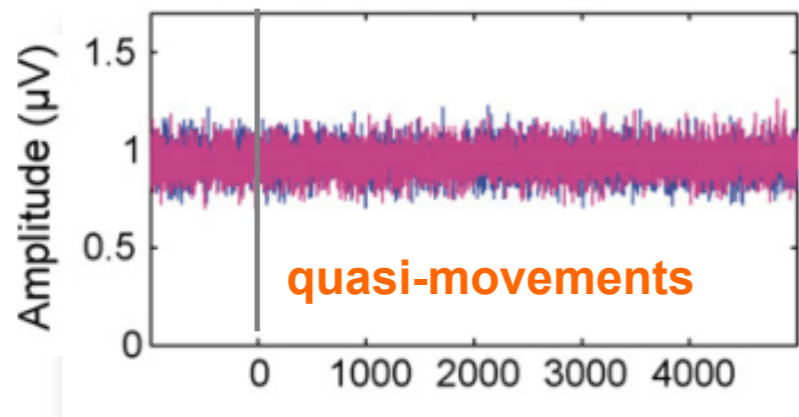
motor threshold



quasi-movements...a fine-graded motor skill



averaged EMG (single subject)

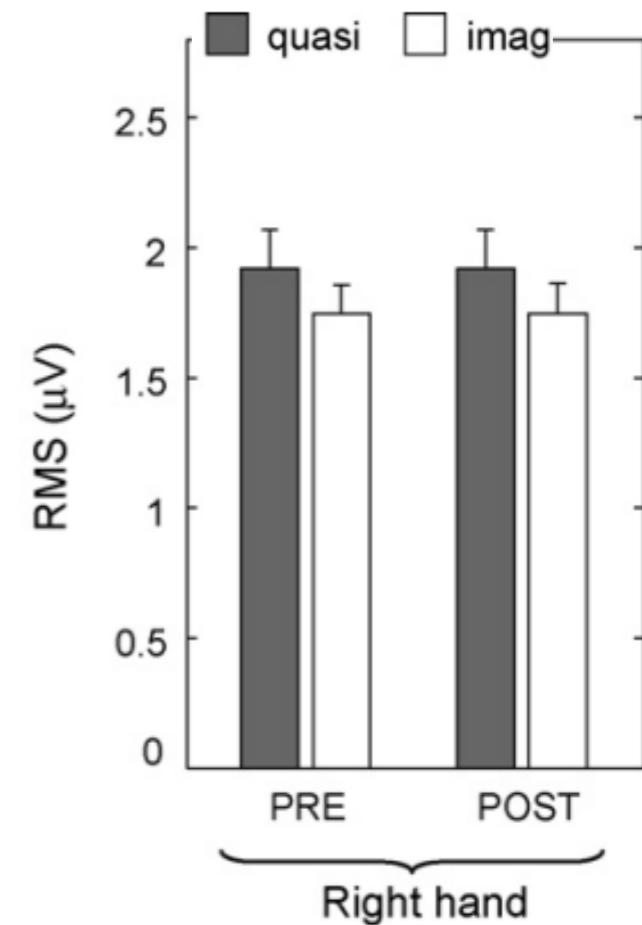


right APB



similar results
for left APB

grand-average EMG

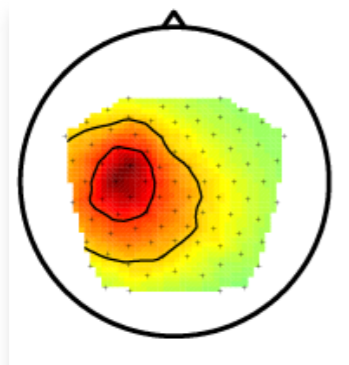


- no significant differences between pre- and post-stimulus EMG
- no differences between QM and imagery (based on EMG activity)

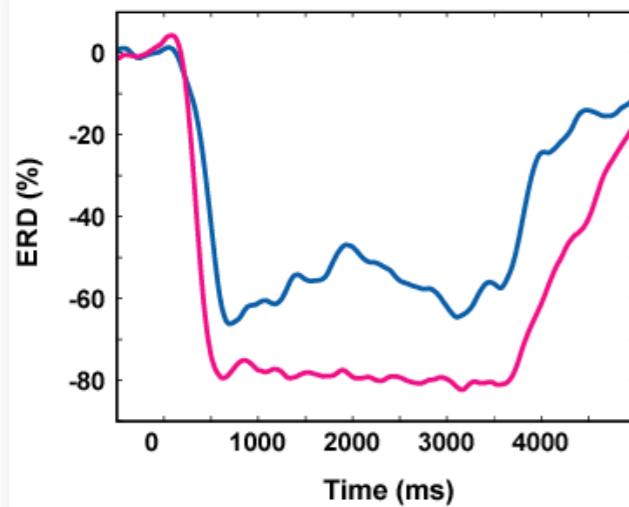
spatial topography of neural activation and event-related desynchronization (8–13 Hz)



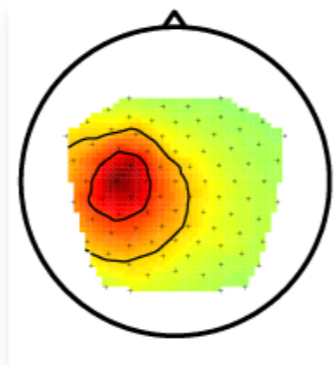
overt movement



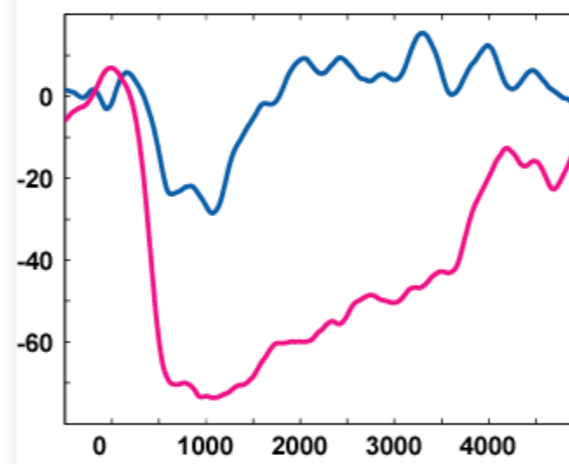
C3



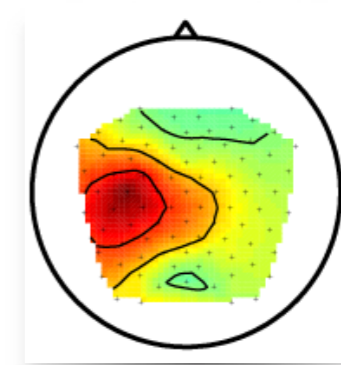
quasi-movements



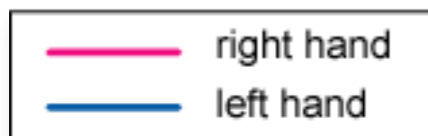
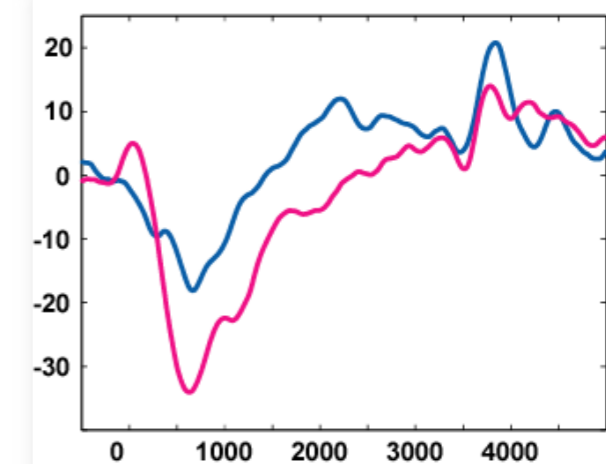
C3



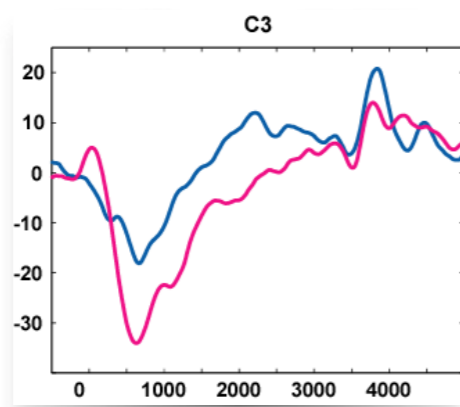
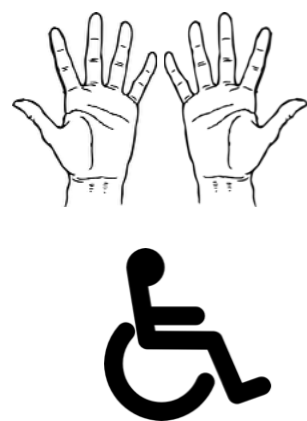
motor imagery



C3



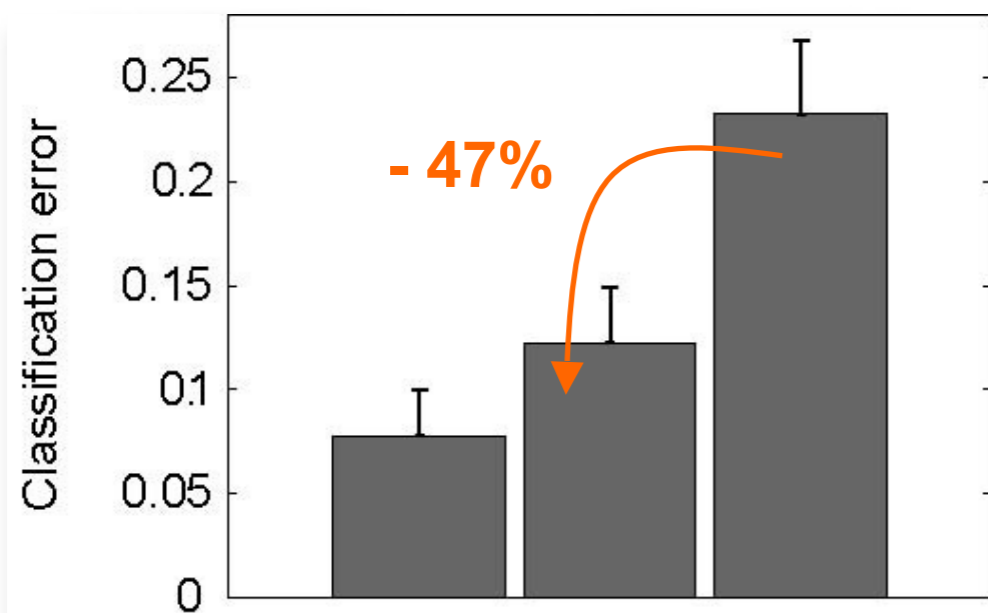
ERD in contralateral hemisphere:
movement > **quasi** > imagery



brain-computer interface (BCI)

- **discriminate** brain states related to **motor cognition**, e.g., **imagine** left vs. right hand movement
- for **patients** (paralysis, amputation, coma...)
- algorithms/mental strategies tested in **healthy** subjects
- **illiteracy problem!**

EEG classification error



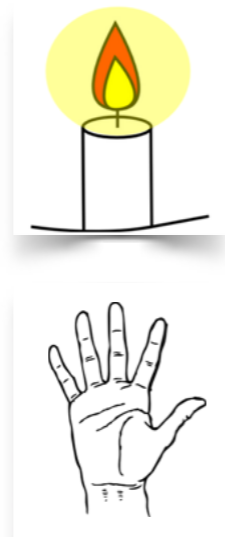
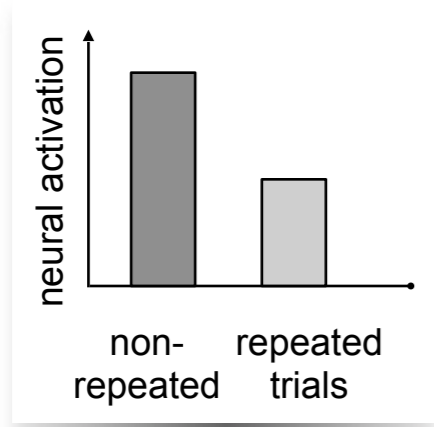
move quasi imagery

Nikulin*, Hohlefeld* et al. (2008)

quasi-movements

- increased classification accuracy **~ 47%** (up to **86 %**) compared to standard imagery
- not related to occasional EMG responses
- effective for BCI (illiterate problem)
- healthy subjects \Leftrightarrow patients

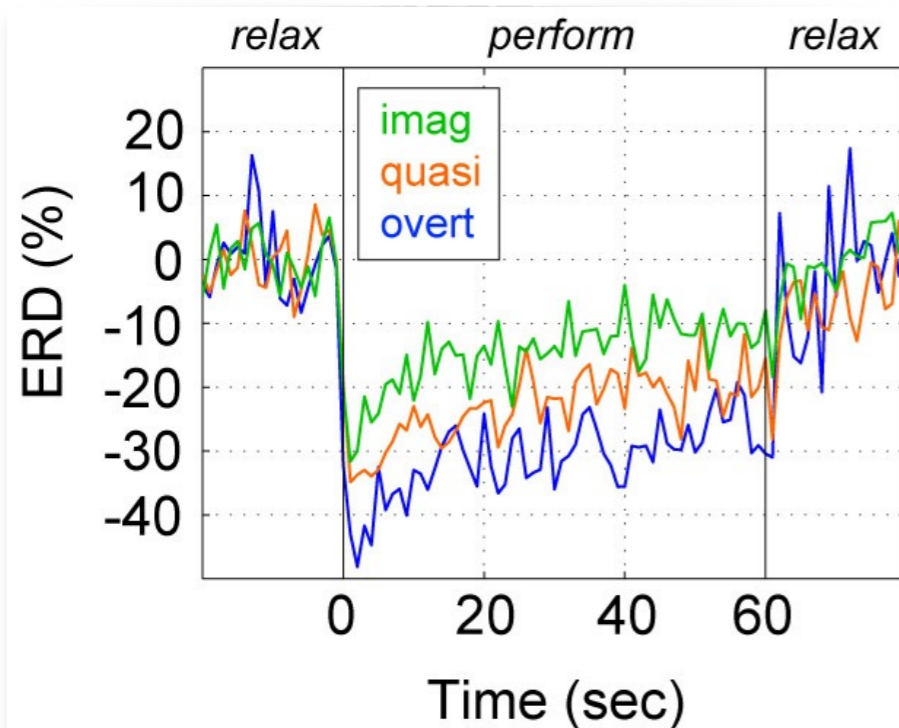
repetition suppression



repetition suppression (RS) is found with...

- **afferent**: stimulation Grill-Spector et al. (2001)
- **efferent**: movement Wu et al. (2008)
- open question: **internally (central)** triggered RS?

Laplacian ERD, C3 contra,
grand-average (n=13), 9–12 Hz



RS in **covert** movements (EEG)

- motor RS primarily due to **central activation**
- **quasi-movements**: α -ERD **~10 sec longer** sustained than motor imagery

- long-range temporal correlations (“fractals”) in basal ganglia
- functional/effective connectivity in/between basal ganglia

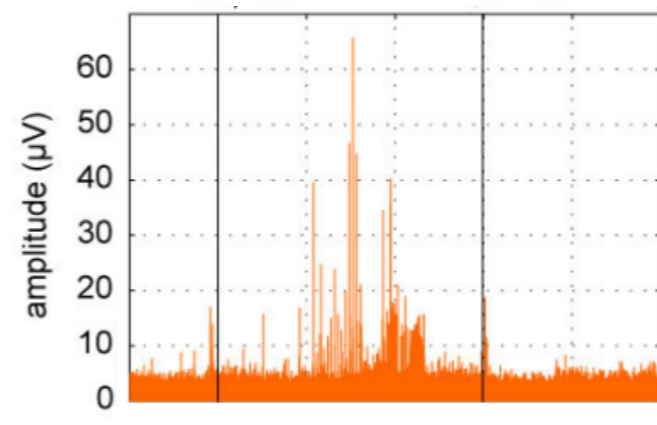
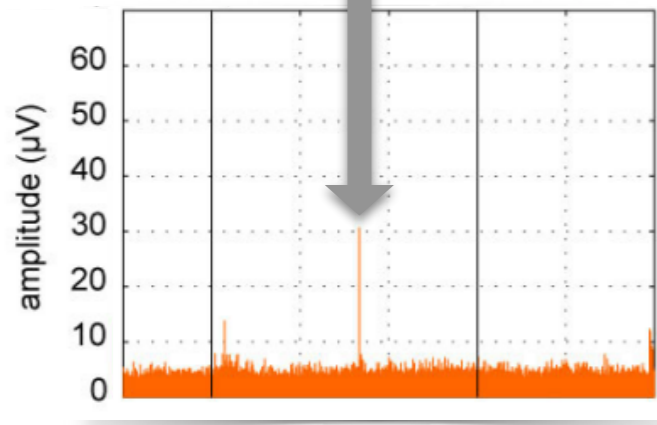
covert vs. overt movement stages

- muscle **contraction** is just the **end stage**
- brain activity during covert stages: **intention** matters!
- different intentions: brings the motor system **closer** to **motor threshold**

EEG correlates of quasi-movements

- **quasi-movements**: **volitional** movements with **zero motor output**
 - ... subjective **reports**: “I am doing a movement” , “I feel the movement”
 - ... **silent EMG** in the majority of trials (comparable to motor imagery)
 - ... **strong EEG activity** over sensorimotor cortices
- effectiveness for **BCI**
- overcome the **mixture** challenge of efferent vs. reafferent signals
- covert stages: **internal repetition suppression**

~1% maximum
voluntary contraction



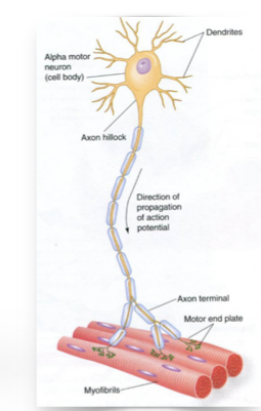
EMG detection rate
during quasi-movements:
~20 %

Nikulin*, Hohlefeld*
et al. (2008)

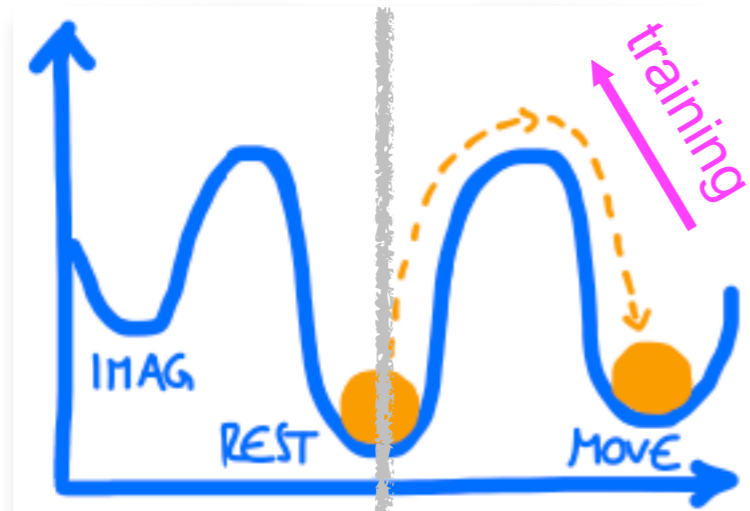
more
training?

occasional mini “motor slips”
during quasi-movements:
a window into “phase transitions” in the motor system
between rest and movement?

quantum of action — 1 motor unit
subquantum — quasi-movements
Prof. G. Curio (personal communication, 2014)



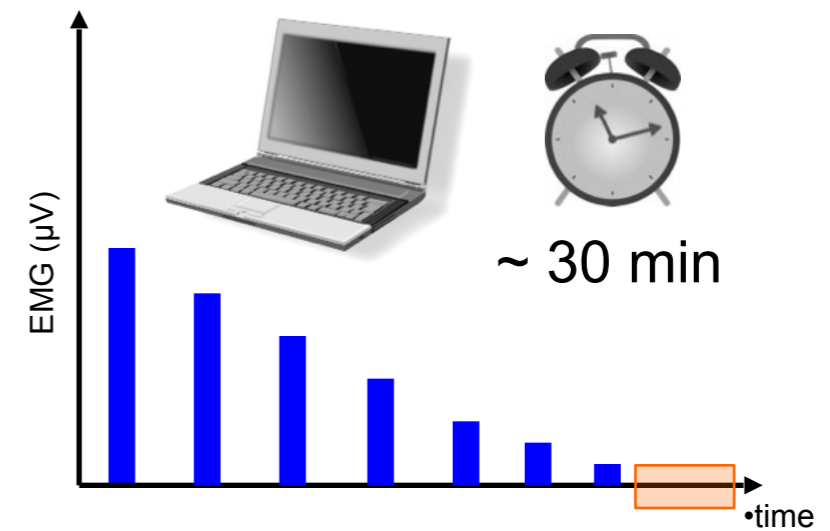
before training



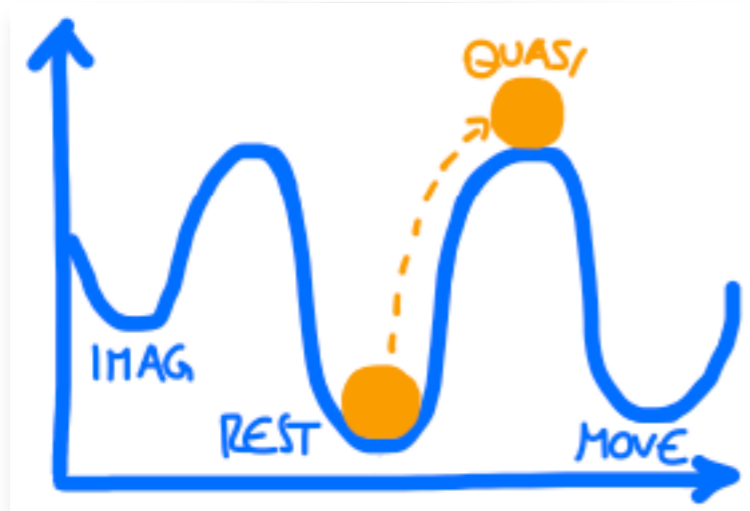
movement **simulation** | movement **intention**



EMG neurofeedback



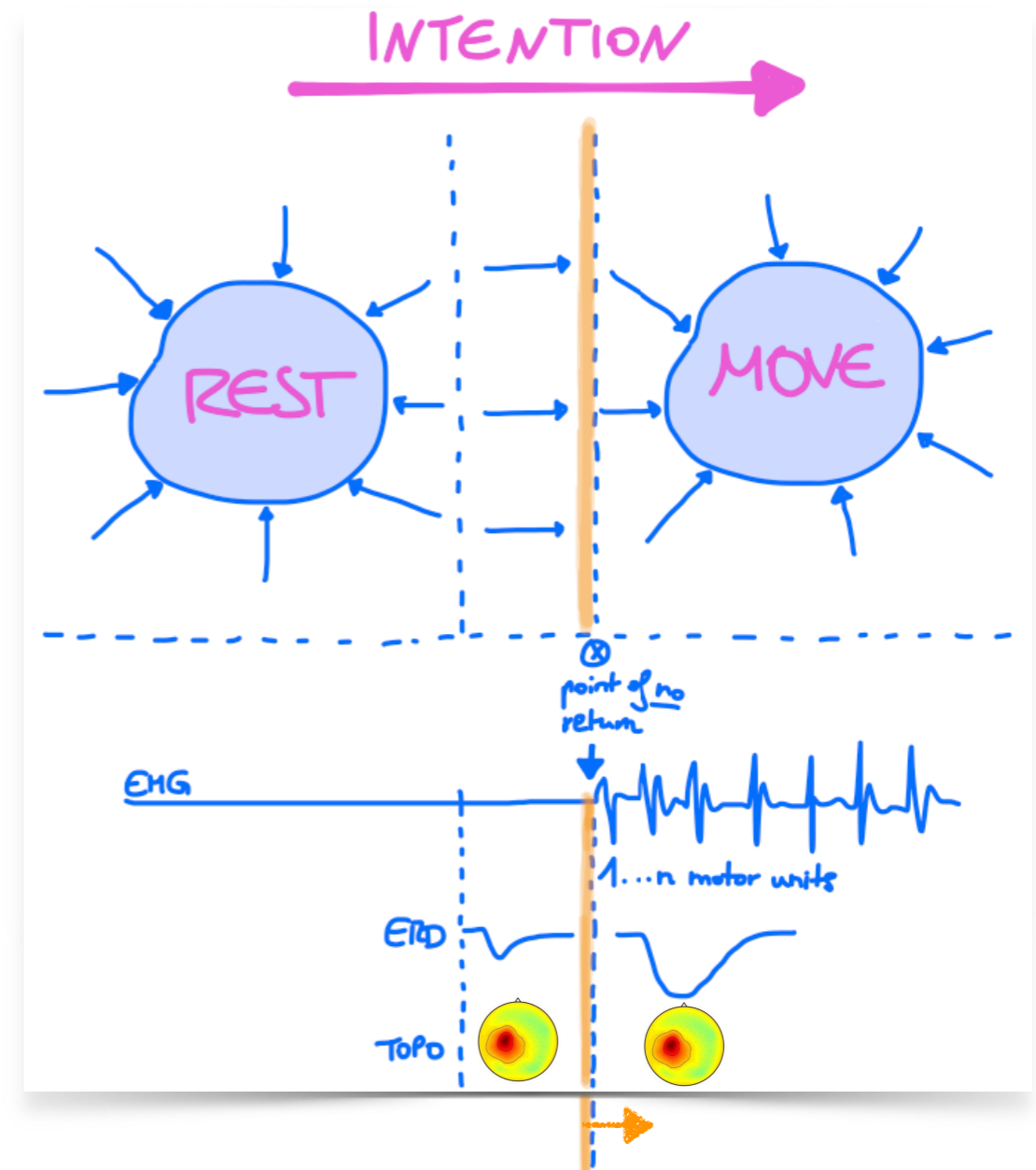
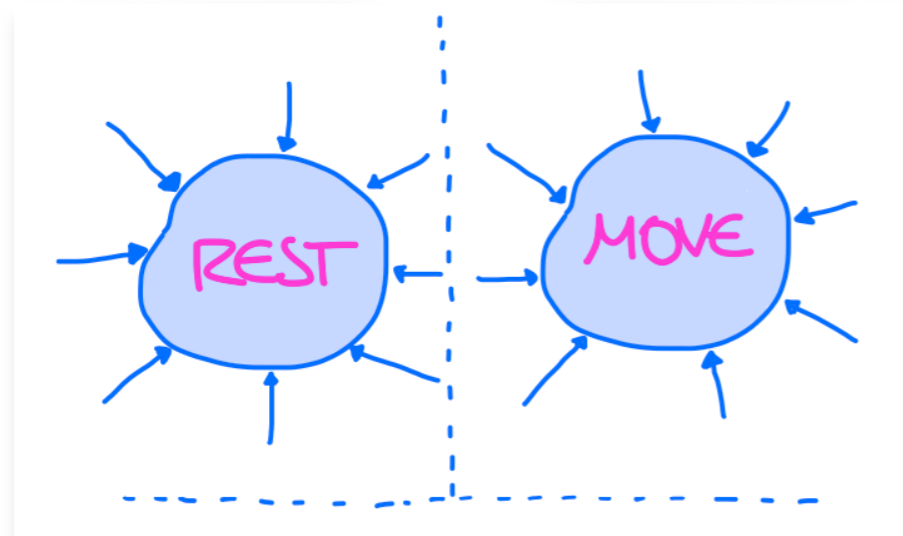
training



after training



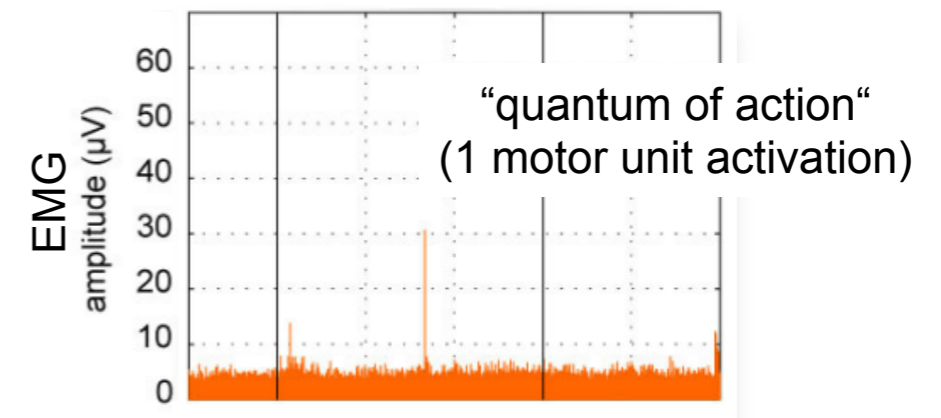
attractor landscapes in the motor system



spontaneous fluctuations

- neural noise
- attention, drowsiness, motivation...

might determine occurrence of motor slips
 ...“transition“ rest—movement?



methods (Parkinson patients)

- long-range temporal correlations
- connectivity (\neq volume conduction)

paradigm

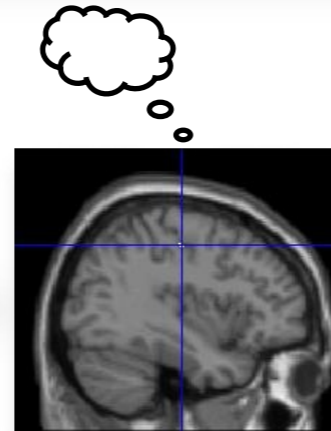
- quasi-movements:
"subquantum" of action

applications (QM)

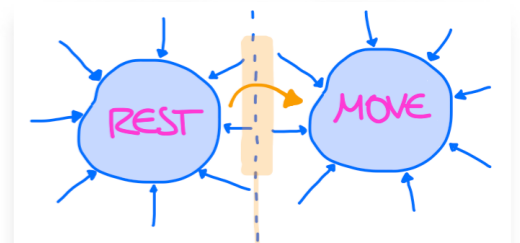
- brain-computer interface
- intention
- repetition suppression
- movement dynamics
("phase transitions")

I choose
.....
imagine
quasi

to move.



...to move **AND** not to move



"What is left over if I subtract the fact that ~~my arm goes up~~
from the fact that I raise my arm?"

L. Wittgenstein (1953)