Donders Institute
for Brain, Cognition and Behaviour

Brain Computer Interfacing II

Induced Response:
Imagined Movement

4 Oct 2011

Ruud Meulenbroek

Radboud University Nijmegen

Overview

1. Redundancy
2. Motor Tasks – dimensions
3. Motor Imagery
   - Definition
   - Applications
   - Claim and models
   - Behavioural studies
   - Neurocognitive studies
4. Example of BCI-related study

Task

Imagine writing the letter ‘A’....

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Task

Imagine writing the letter ‘A’....

Abbs, J.H.; Cole, K.J.(1987) Neural Mechanisms of Motor Equivalence and Goal Achievment In S.P. Wise(Ed.), Higher Brain Functions: Recent explorations of the BrainÕs Emergent Properties. Chapter 2.(pp.15-43)John Wiley&Sons
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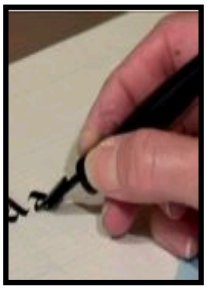
Task

Imagine writing the letter ‘A’....

or



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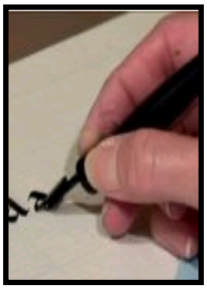

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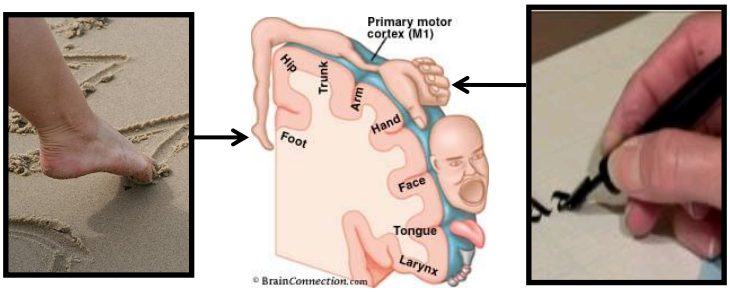

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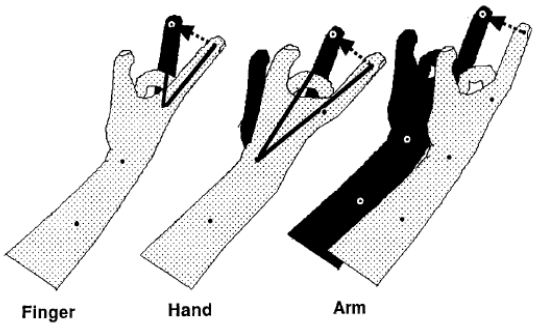
Motor equivalence

Motor tasks can be realized in multiple ways



Vaughan, J., Rosenbaum, D., Diedrich, F., Moore, C., (1996), Cooperative selection of movements: The optimal selection model, Psychological Research, 58, pp 254-273.

Motor equivalence

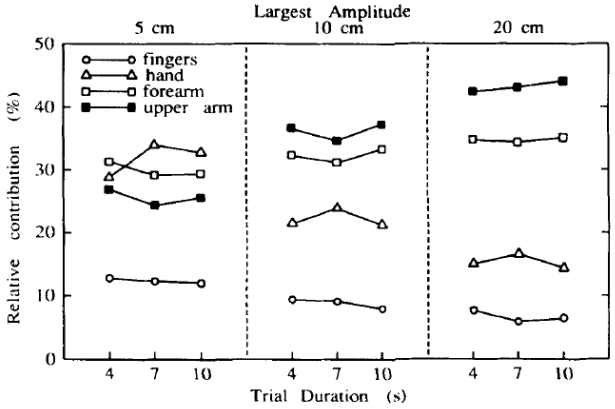


FIG. 6. Relative contribution of limb segments as a function of Largest Amplitude and Trial Duration.

Meulenbroek, R.G.J., Rosenbaum, D.A., Thomassen, A.J.W.M., & Schomaker, L.R.B. (1993). Limb-segment selection in drawing behavior. Quarterly Journal of Experimental Psychology, 46, 273-299.

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Motor tasks may have multiple goals

1. Spatial
2. Temporal
3. Force
4. ...any combination

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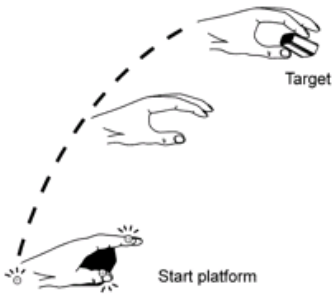
Motor tasks may have multiple parameters

1. Direction
2. Force
3. Amplitude
4. Speed
5. Acceleration
6. Torque
7. ...



J Neurophysiol 105: 1603–1619, 2011.

Arjun K. Bansal,[1] Carlos E. Vargas-Irwin,[1] Wilson Truccolo,[1,2,3,4] and John P. Donoghue[1,2,4]

Relationships among low-frequency local field potentials, spiking activity, and three-dimensional reach and grasp kinematics in primary motor and ventral premotor cortices

Internal transformation of information

1. Task dimensions
2. Joint configurations
3. Muscle activations
4. Motor commands

One-to-many mappings !

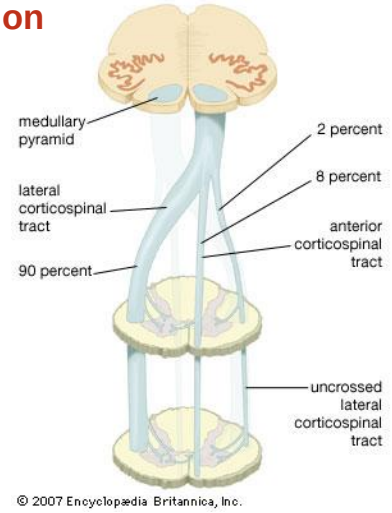
...supported by...

Many neural structures

- Parietal-frontal cortex
- Premotor cortex
- Supplementary motor area
- Motor cortex
- Basal ganglia
- Cerebellum

Proximodistal organization

1. Proximal muscles are close to the trunk
2. Distal muscles control the fingers
3. Proximal muscles are bilaterally controlled
4. Distal muscles are contralaterally controlled



Motor Imagery

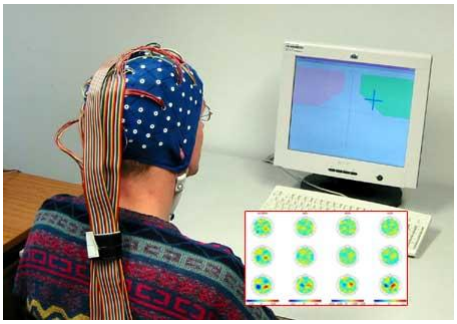
1. Internally simulating an action
2. People “see” an imaginal performance routine or ”feel” the swing of the bat
3. Person is aware of imagining things, which separates mental imagery from dreaming
4. There are no sensory antecedents

Visual vs kinesthetic instruction:
- See: 1st or 3rd person perspective?
- Feel: afferent

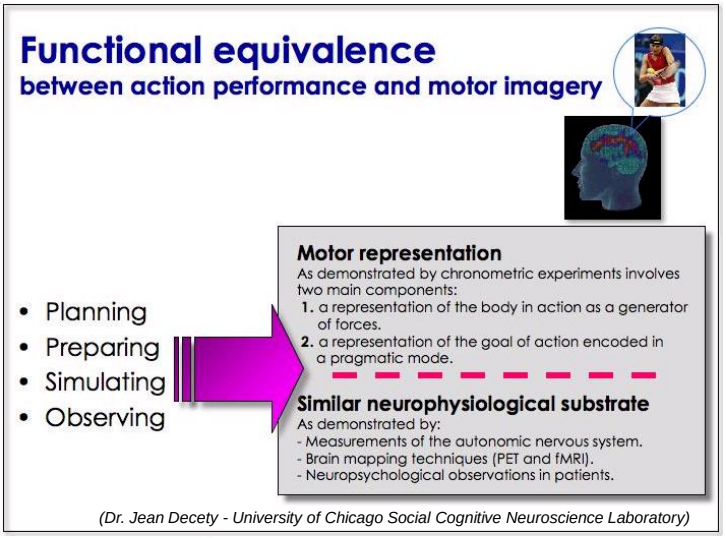
Decety, J., & Grezes, J. (2006). The power of simulation: Imagining one's own and other's behavior. Brain Research, 1079, 4-14.

Applications

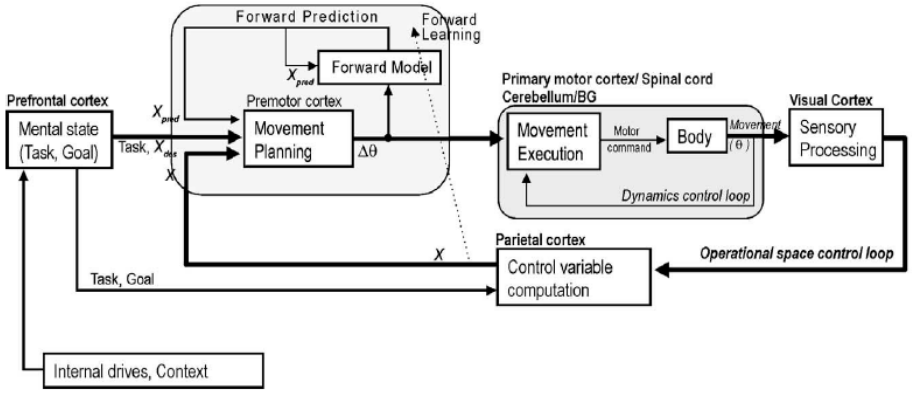
1. Multi-trial
   - Sports
   - Rehabilitation after stroke
2. Single-trial
   - BCI



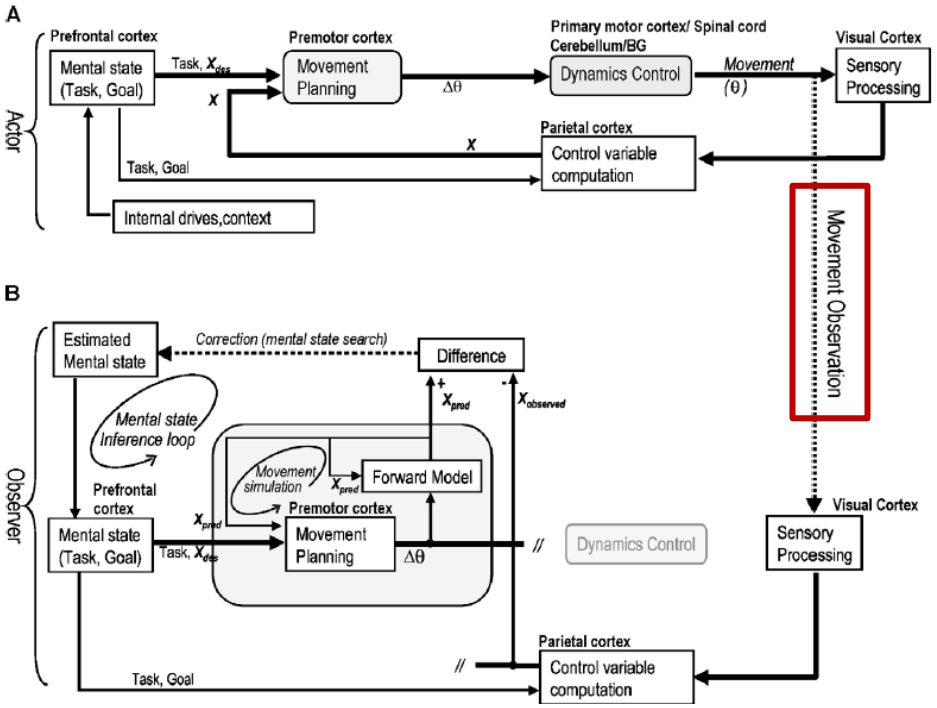
Claim



Movement planning, observation and simulation



Oztop E, Wolpert D, Kawato M (2005) Mental state inference using visual control parameters. Cogn Brain Res 22: 129-151



Mental-practice effect study

Question:

Is mental practice an effective skill-acquisition strategy?

Method:

Between-subjects, pre-post-test design with 4 groups:

1.Physical Practice (PP)

2.Mental Practice (MP)

3.Combination of PP and MP

4.No Practice (NP)

Feltz, D.L., & Landers, D.M. (1983). The effects of mental practice on motor skill learning and performance: A meta-analysis. *Journal of Sport Psychology, 5,* 25-57.
Weinberg, R.S. (1986). The relation between mental preparation strategies and motor performance: A review and critique. *Quest, 33,* 195-213.

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Mental-practice effect study

Results:

– Subject in MP-group will perform 0.5 SD better than subject in NP-group (Feltz & Landers, 1983)

– MP alternated with PP is more effective than either alone (Weinberg, 1986)

Feltz, D.L., & Landers, D.M. (1983). The effects of mental practice on motor skill learning and performance: A meta-analysis. *Journal of Sport Psychology, 5,* 25-57.
Weinberg, R.S. (1986). The relation between mental preparation strategies and motor performance: A review and critique. *Quest, 33,* 195-213.

Problems with the 'mental practice' model

What can mentally practicing 'a tennis service' mean?

- Thinking about serving
- Talking yourself through the steps of serving
- Imagining an expert hitting a perfect serve
- Visualizing a perfect serve you once hit

Measurement of treatment effects are not well defined

Motor imagery is theoretically not well grounded

- see Suinn (1997)

Suinn, R.M. (1997). Mental Practice in Sport Psychology: Where Have We Been, Where Do We Go? *Clinical Psychology: Science and Practicem 4(3),* 189-207.

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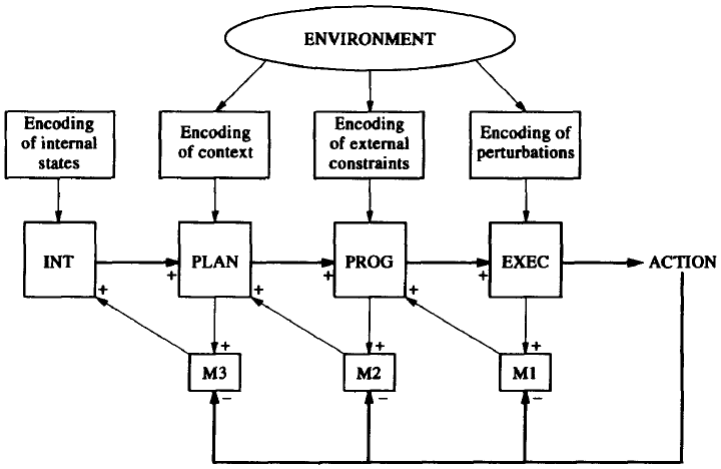
Problems with the 'mental practice' model

- Motor imagery is explicit processing of motor skills that rely on implicit processing...
- Mental imagery tends to activate prefrontal regions for the simple reason that they ask the subject to engage working memory and executive attention; actual motion, however, tends to deactivate prefrontal regions...
- Imagining and executing an action recruit distinct but partially overlapping neural circuits...

Dietrich. A. (2008). Imaging the imagination: The problem with motor imagery. *Methods. doi:10.1016/j.ymeth.2008.04.004*

A model of self-generated action



Jeannerod, M. (1995). Mental imagery in the motor context. *Neuropsychologica, 33 (11),* 1419-1432.

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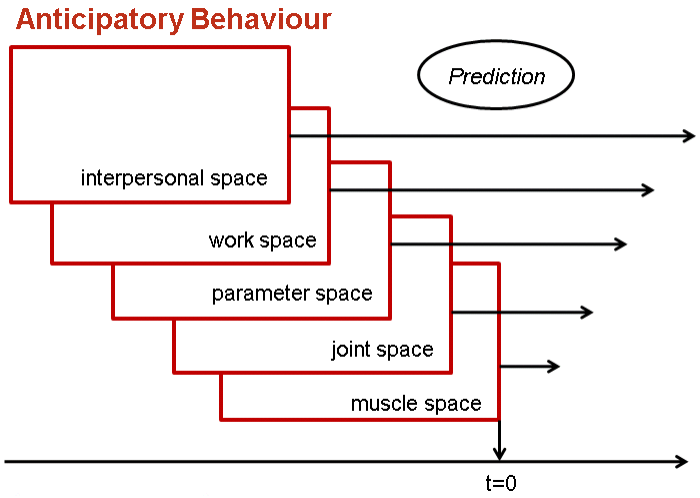
A model of self-generated action



Meulenbroek et al. (in press). *New Ideas in Psychology* .

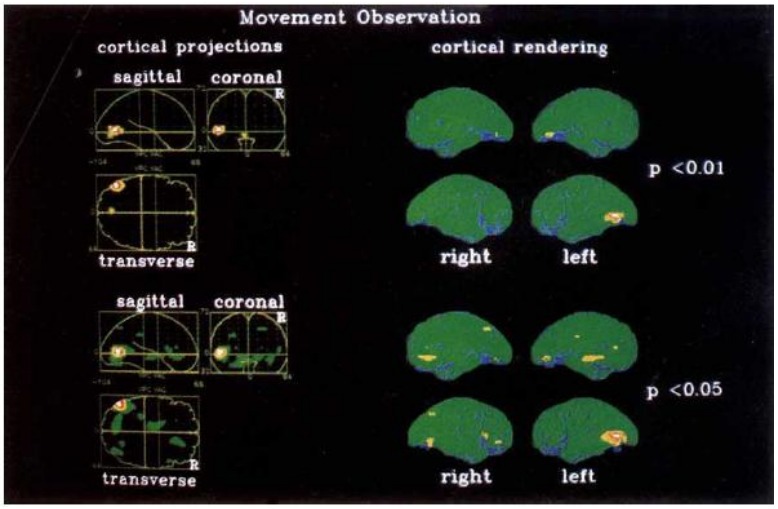
Motor representations in the brain

• BRAIN activity was mapped in normal subjects during passive observation of the grasping movements of an 'alien' hand and while imagining grasping objects with their own hand.

• None of the tasks required actual movement.

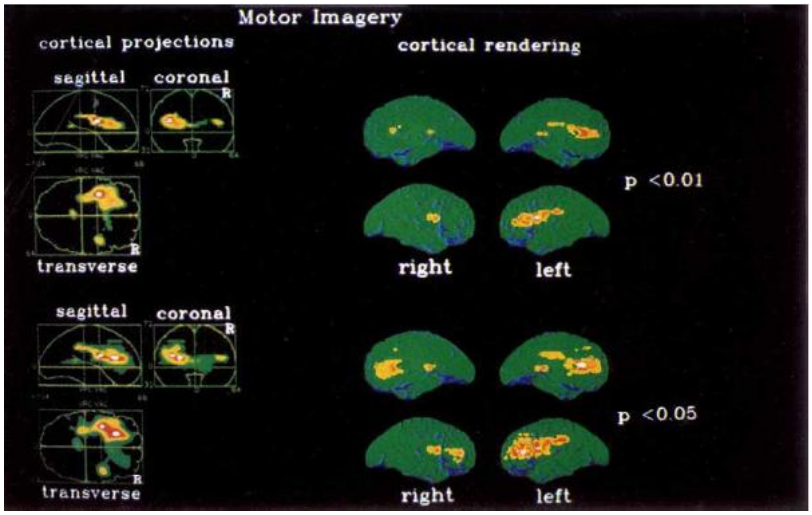
• Shifting from one mental task to the other greatly changed the pattern of brain activation.

Decety , J. et al. Mapping motor representations with positron emission tomography. *Letters to Nature, 317,* 600-602.



Decety , J. et al. (1994). Mapping motor representations with positron emission tomography. *Letters to Nature, 317,* 600-602.

Motor Imagery



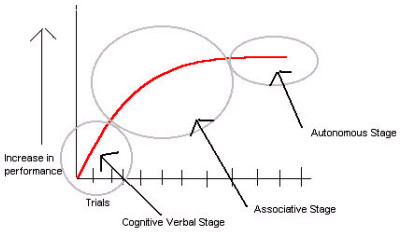
Decety , J. et al. (1994). Mapping motor representations with positron emission tomography. *Letters to Nature, 317,* 600-602.

Motor representations in the brain: multimodality

•During observation of hand movements, activation was mainly found in visual cortical areas, but also in subcortical areas involved in motor behaviour, such as the basal ganglia and the cerebellum.

• During motor imagery, cortical and subcortical areas related to motor preparation and programming were strongly activated.

• These data support the notion that motor learning during observation of movements and mental practice involves rehearsal of neural pathways related to cognitive stages of motor control.



Pülvermuller (2005). Action verbs activate motor areas.

Decety , J. et al. (1994). Mapping motor representations with positron emission tomography. *Letters to Nature, 317,* 600-602.

Posture influences motor imagery

Assumption

- Motor imagery is an embodied cognitive process involving a simulation of movements of one's own body

Question

- Is motor imagery influenced by the physical configuration of one's own body?

De Lange, F. P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery. *Neuroimage, 33,* 609-617.

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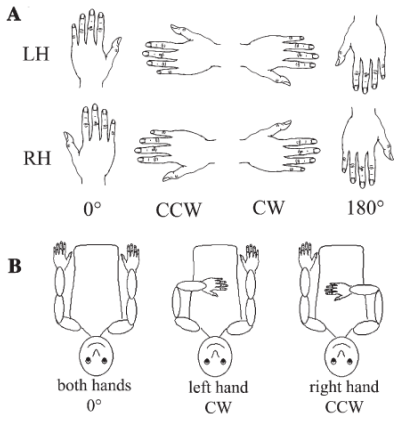
Posture influences motor imagery

Task:

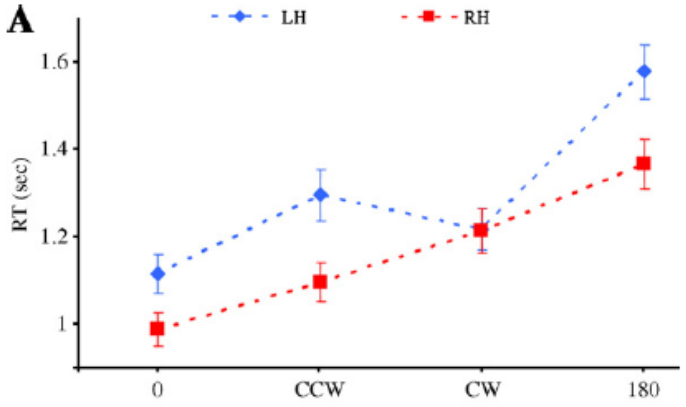
"Do you see a right hand or a left hand?"

This approach exploits the fact that rotating right hands in clockwise orientations requires biomechanically more complex movements than counterclockwise rotations, whereas the opposite holds true for left hands.



De Lange, F. P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery. *Neuroimage, 33,* 609-617.

Posture influences motor imagery



De Lange, F. P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery. *Neuroimage, 33,* 609-617.

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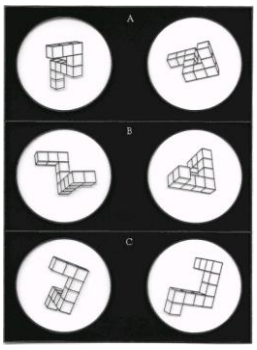
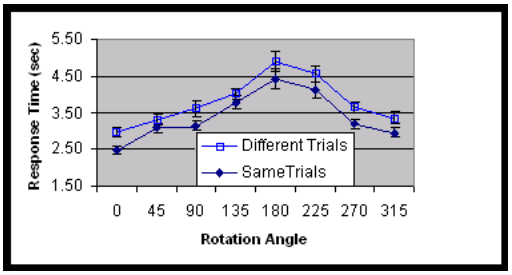
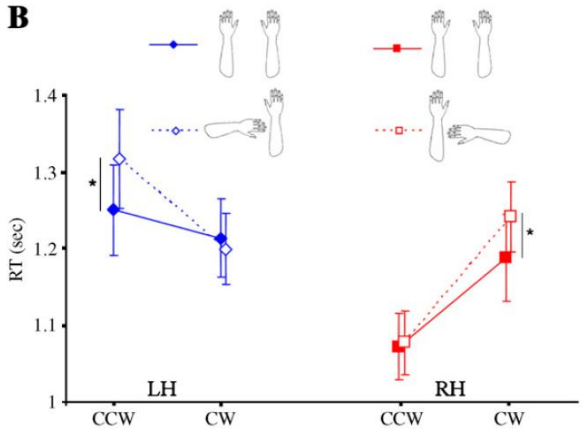
Mental rotation-angle is reflected in RT





Shepard, R.N. & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171*, 701-703.

Posture influences motor imagery



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Imagined Movement

Posture influences motor imagery

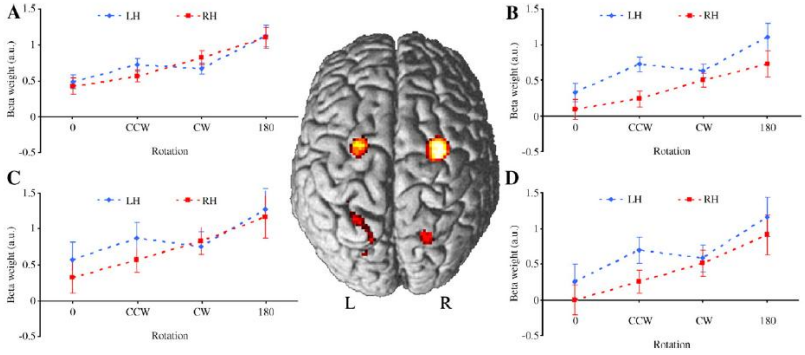

Fig. 3. Neural activity modulated by biomechanical complexity. Plotted are the parameter estimates of the BOLD response (±SEM) of the four regions showing significant orientation-related effects following the arms' biomechanical constraints. For graphical purposes map is thresholded at $T>4.6$. (A) Left PMd. (B) Right PMd. (C) Left IPS. (D) Right IPS.

De Lange, F. P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery. *Neuroimage, 33,* 609-617.

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Posture influences motor imagery

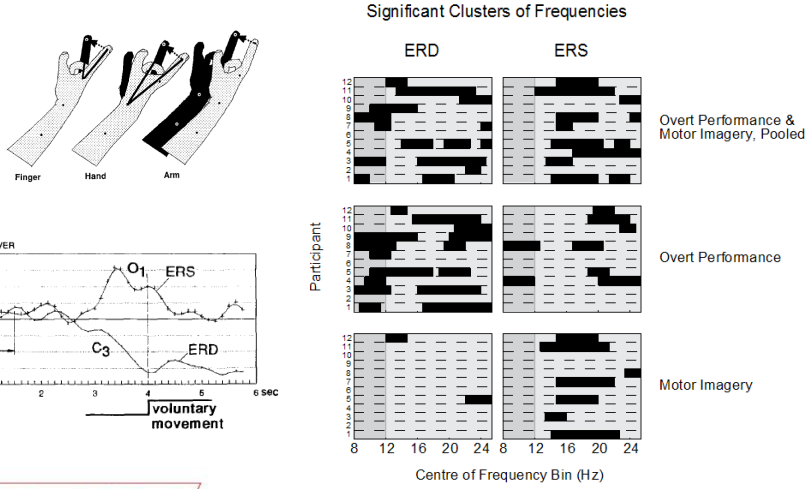
Conclusion

1. Mental rotation of left and right hands followed the biomechanical constraints of the left and right hand, and showed increases obeying these constraints in a specific bilateral parieto-frontal circuit.
2. Within this circuit, the right hemisphere was preferentially activated for left hand movements, whereas the left hemisphere was active for both left and right hands.
3. Moreover, behavioral performance and activity in the intraparietal sulcus was influenced by subjects' own arm posture.
4. **These findings illustrate the embodied nature of imagined movements and point to a specific cerebral site for integrating different sources of information during movement simulation.**

De Lange, F. P., Helmich, R.C., & Toni, I. (2006). Posture influences motor imagery. *Neuroimage, 33,* 609-617.

Optimal selection model and BCI

(Jesse van de Muijden – rm CNS student)



Take home messages

- Motor imagery
  - ✓ Complex cognitive process
  - ✓ Activates many neural structures
  - ✓ Tasks need to be precisely designed, instructed, tested
  - ✓ Multi-level representations should not be ignored
  - ✓ One-to-many mappings need to be taken into account

Topics in Jason's lecture

- BCI based on motor imagery
  - ❑ Readiness Potential
  - ❑ Event-Related (De)Synchronisation (ERD/ERS)
  - ❑ Motor imagery paradigm and characteristics for BCI
  - ❑ Current research (+video)
  - ❑ Time-locked motor imagery and variability research
  - ❑ Patient applications