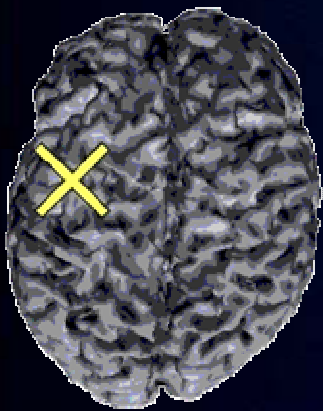


# Navigated Magnetic Stimulation of the Brain

## - A New Brain Mapping Modality -

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Kuopio University Hospital



*“Studying the human brain can be a frustrating business. Although sophisticated imaging techniques can offer snapshots of activity, direct intervention in the brains of humans is ethically off-limits. It is no wonder that neuroscientists sometimes feel like visitors to a museum”*  
(Nature 2002, 417:114-6),

**“THEY CAN LOOK BUT NOT TOUCH.”**

# *Why Navigated Brain Stimulation?*

- Mapping of brain functions
- Planning of surgical operations
- Follow-up of the recovery after trauma or operation
- Treatment
- Basic investigation of brain functions
- Investigation of brain plasticity

*Navigated Brain Stimulation is the only method to reach into the human brain noninvasively.*

*” No wires and electrodes inside head”*

## TMS WITHOUT NAVIGATION

- Non-navigated TMS
  - Poorly selective stimulation
  - Poor reproducibility
  - High variation in the results
- Inaccurate measurements limit the clinical benefits



## NBS

- Navigated Stimulation
  - Accurate targeting
  - Reproducible locations
  - Reproducible dose
- Routine diagnostic use
- Therapeutic use

Real-time Targeting



# Technical aspects

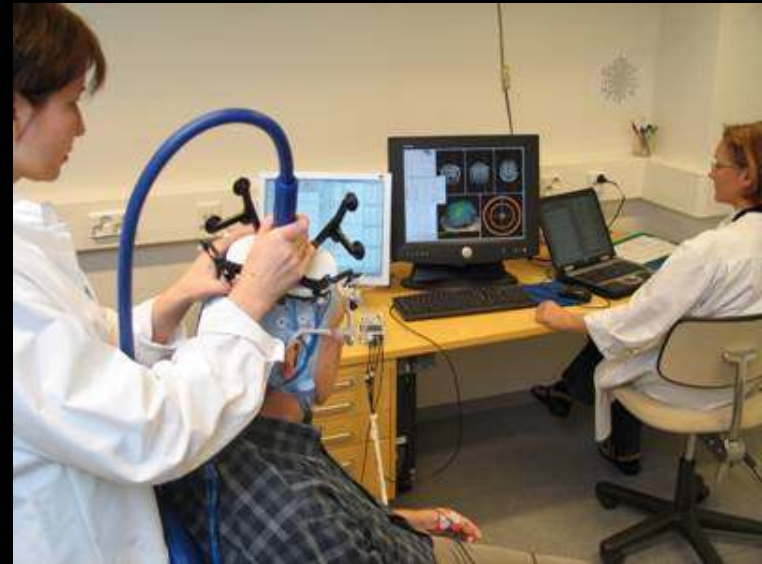
## System consists of:

TMS-instrumentation

IR-camera + Navigation-software

EEG-instrumentation

EMG-instrumentation

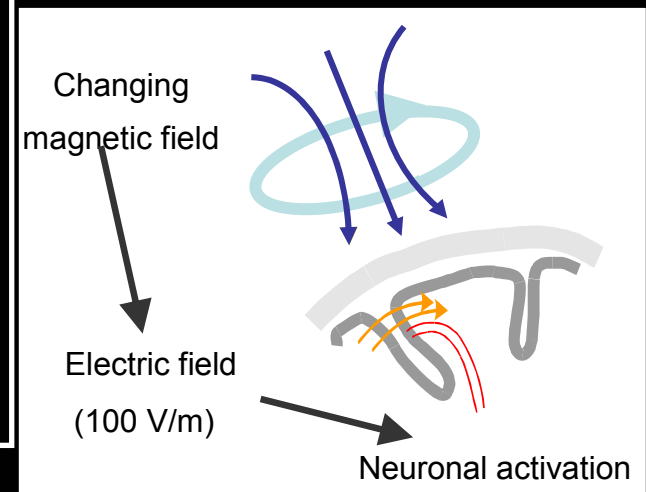


## In numbers:

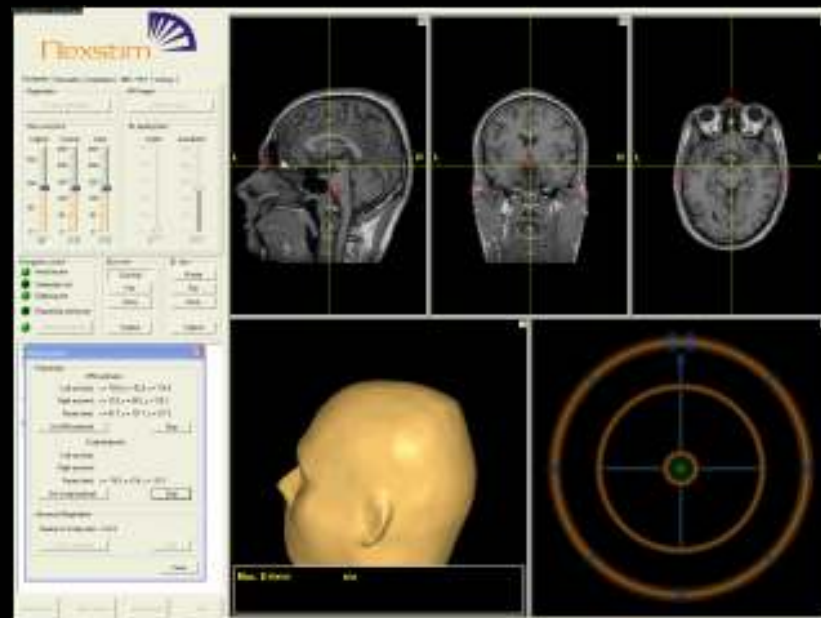
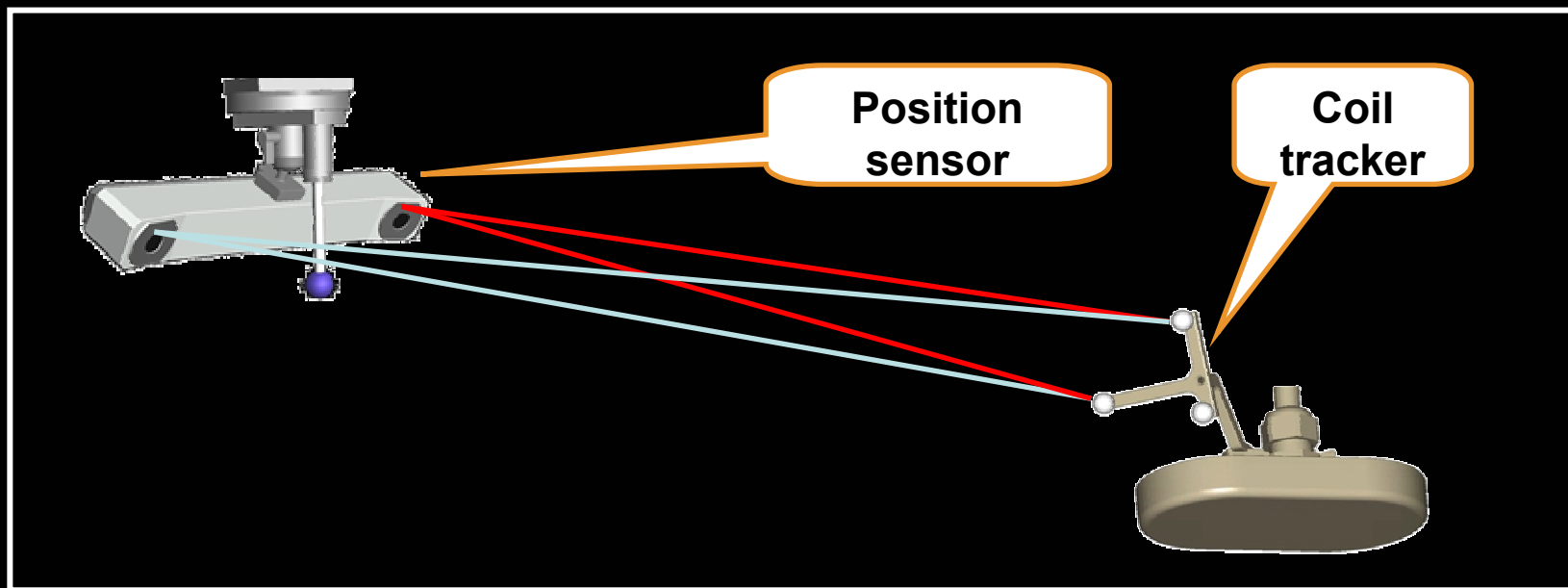
Current: 5-10kA

Magnetic field: 0 >> 2T / 100 mikrosec.

Induced electric field in brain: 100 V/m

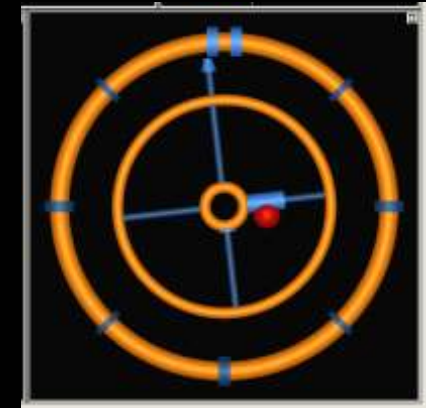


# Matching of head and MR-coordinates

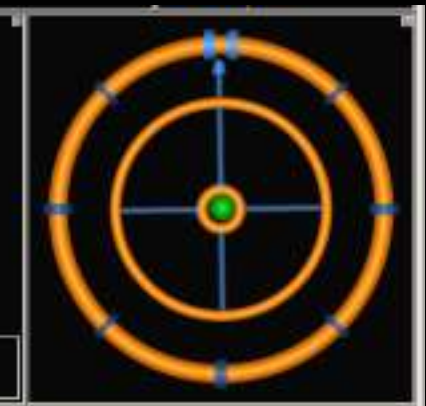
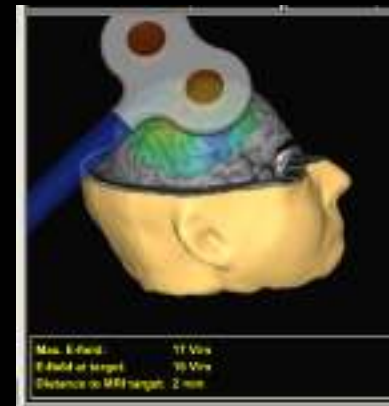


# REPRODUCIBILITY OF NAVIGATION AND DOSE

1. Inaccurate matching of head and MR-coordinates



2. Distortion of MR-image



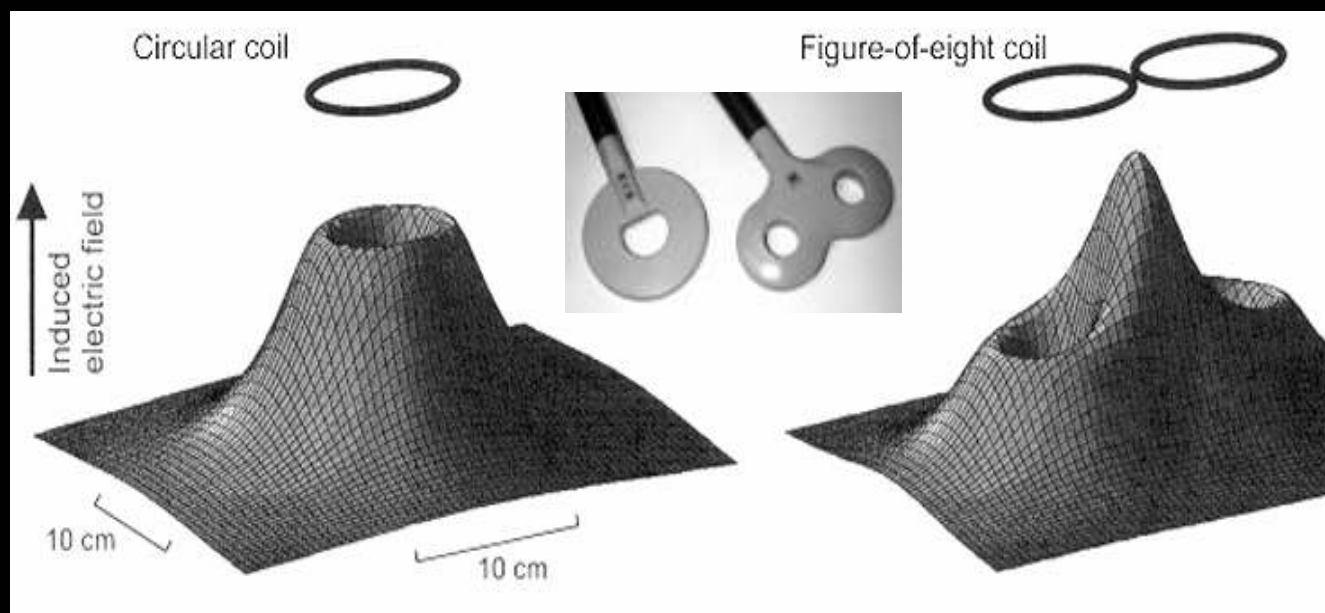
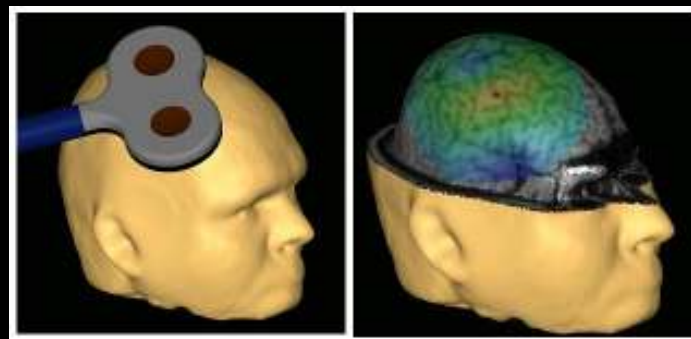
3. Movement of head and coil trackers during measurement



# Induced electric field

- NBS system calculates the electric field in real time

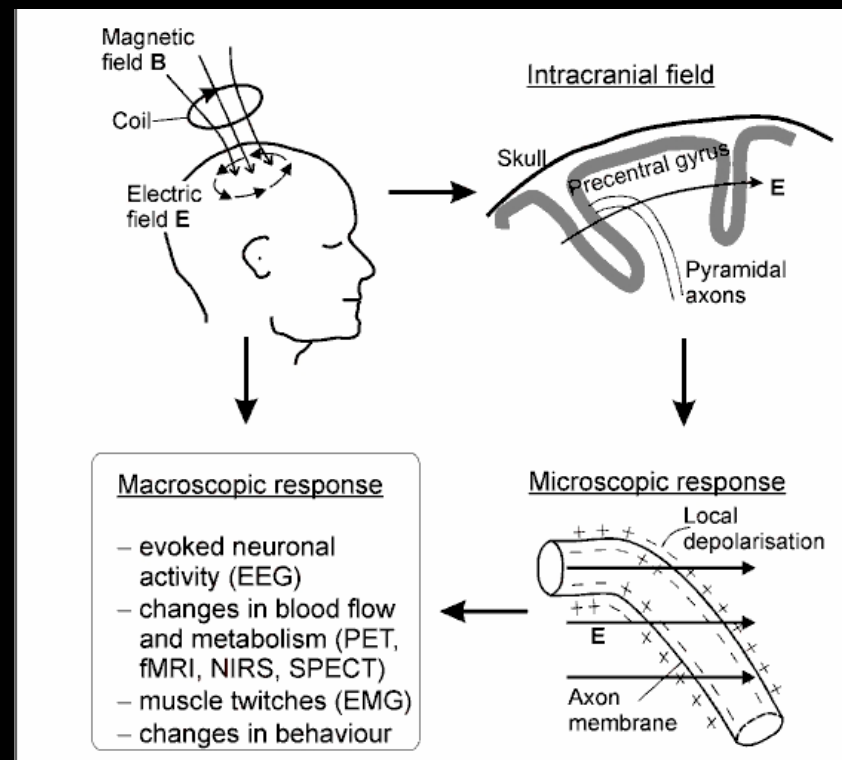
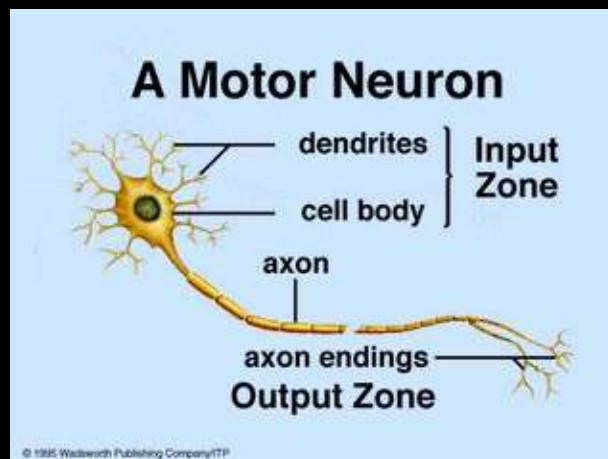
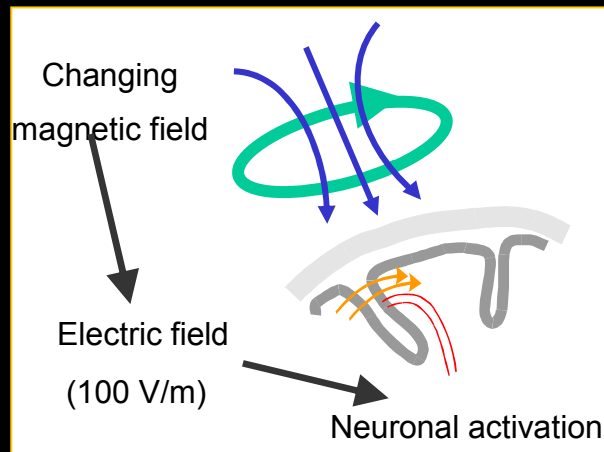
Coil construction and direction of current affect the electric field



# Activation mechanisms

Depolarization is induced effectively when:

1. Electric field is directed across axon
2. There is a gradient in the electric field
3. There is a bend in the axon

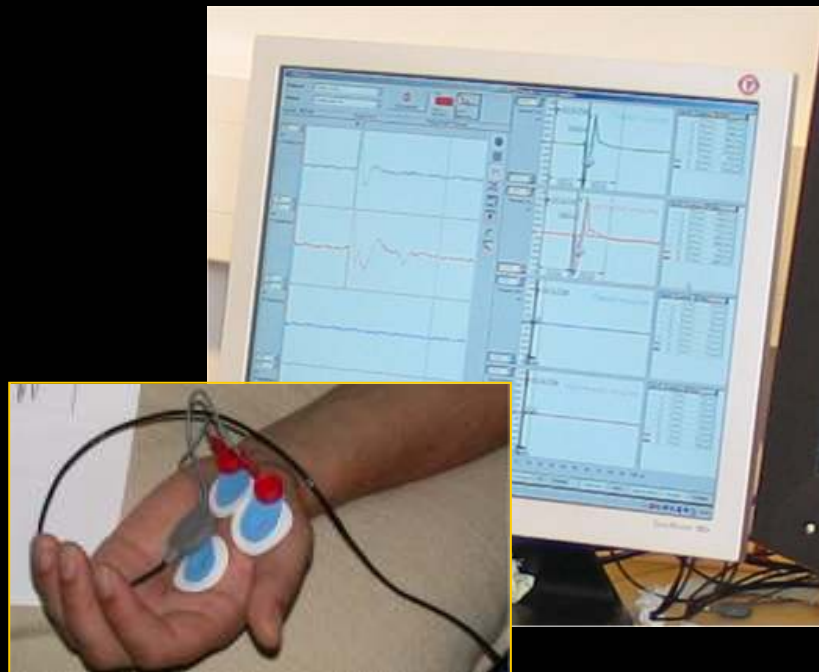




# Monitoring responses

## Motor response

- Bipolar surface EMG
- 8 channels
- Online monitoring

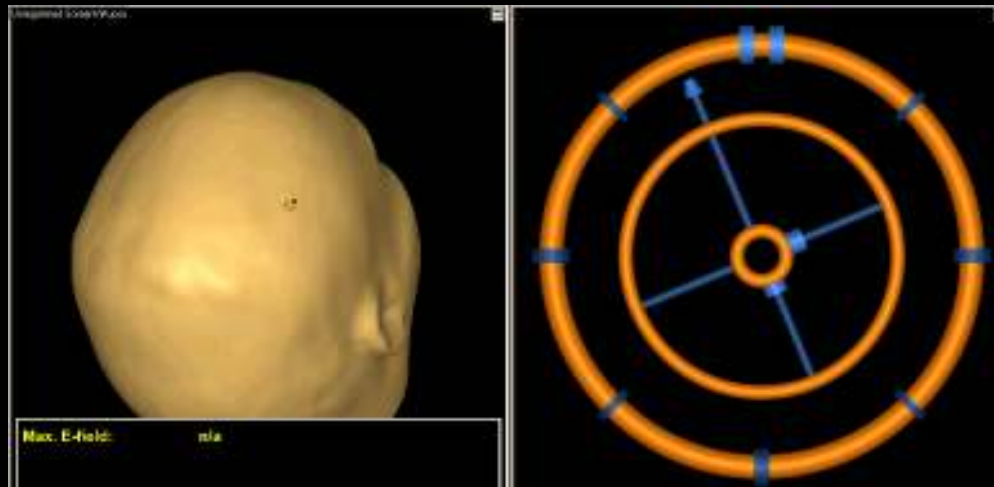
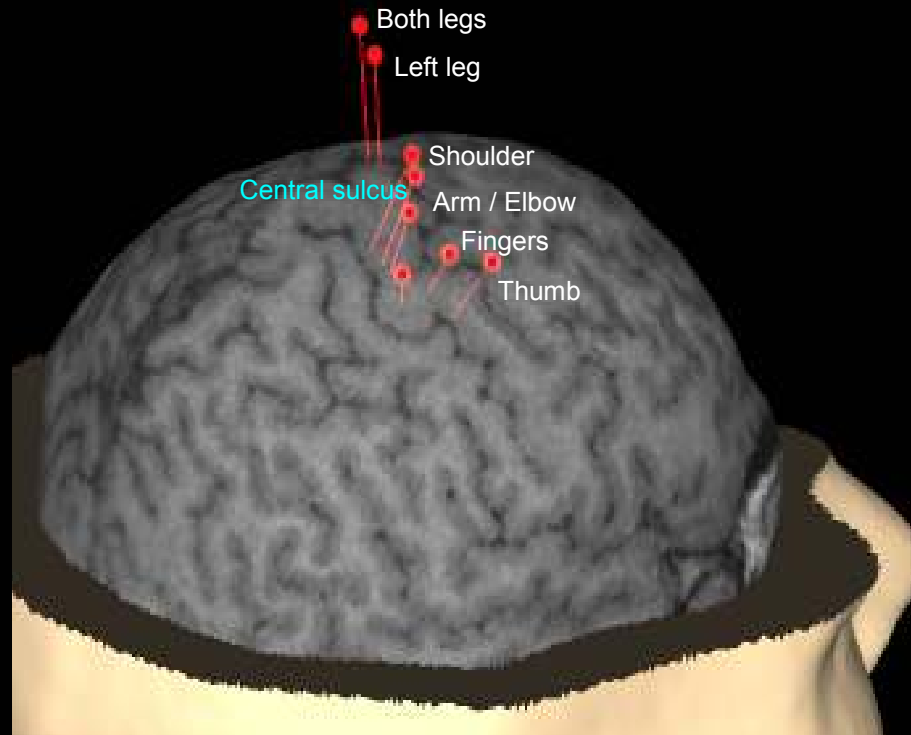


## EEG

- TMS-compatible electrodes
- TMS-compatible amplifiers
- Online monitoring and averaging



# Mapping of motor cortex



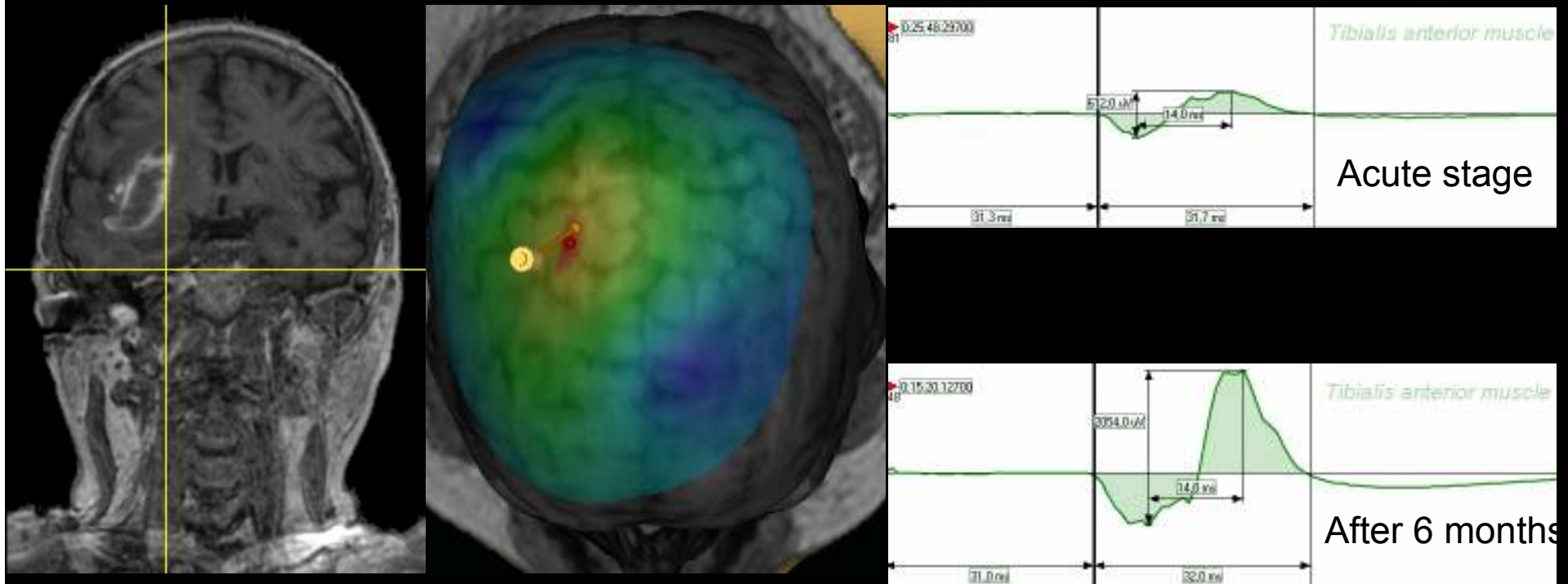
# Application examples

1. Follow-up of recovery after stroke
2. Evaluation of functional changes in brain after stroke
3. Planning of tumour resection
4. Investigation of training induced changes in motor cortex
5. Investigation of cortical connectivity
6. Therapeutic possibilities?

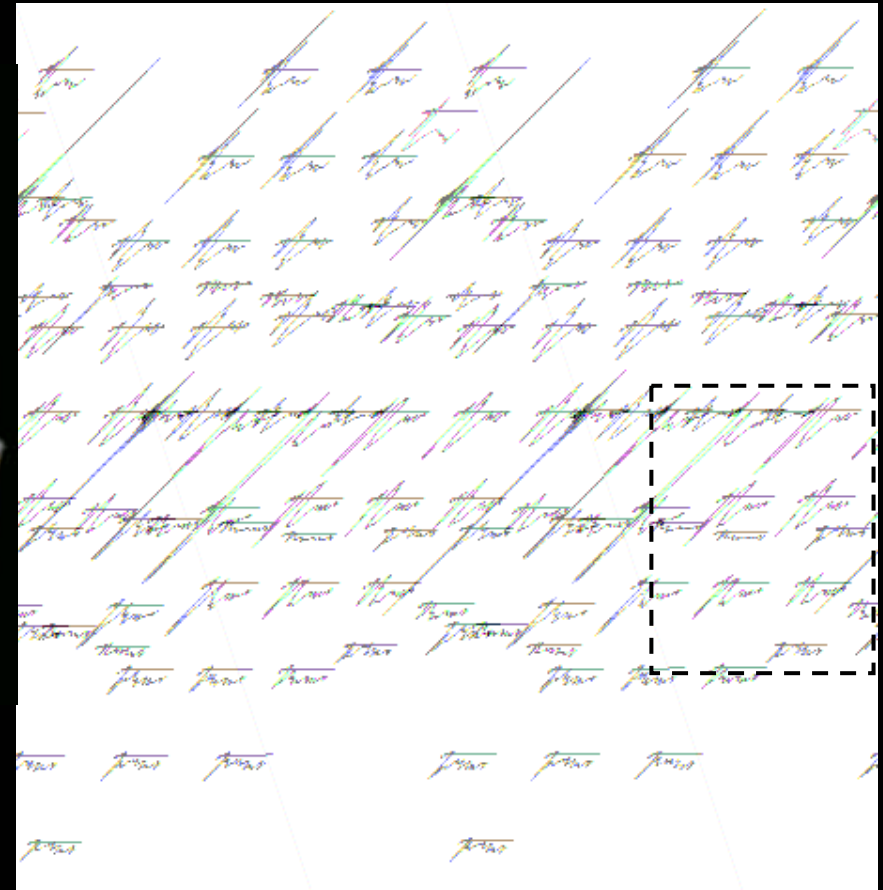
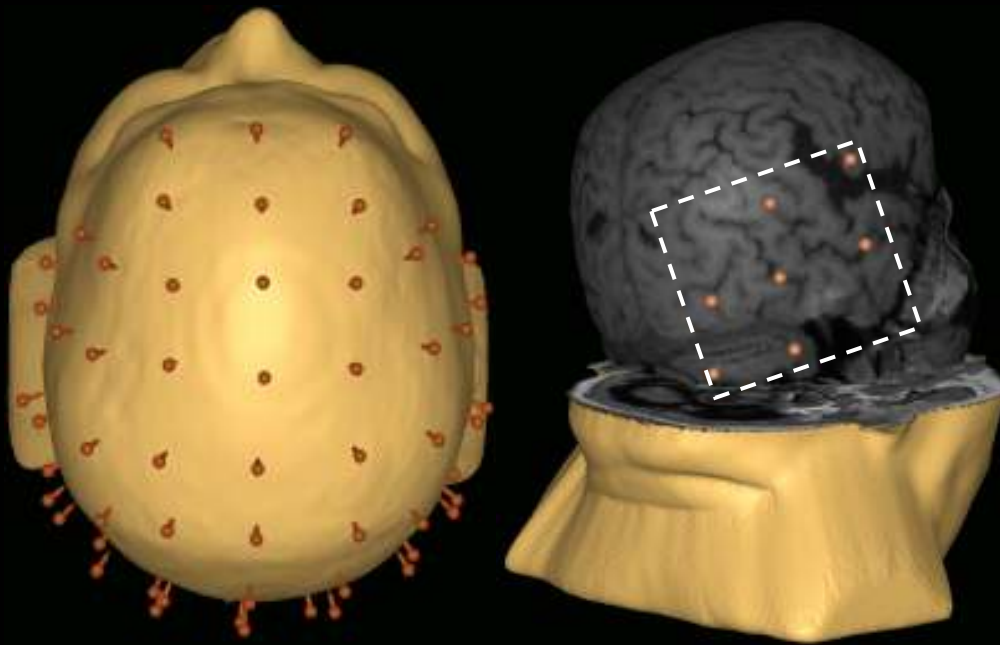
# 1. Follow-up of recovery after stroke

**Case:** 74 years old, physically active lady who suffered from a sudden weakness and partial paresis of left leg and arm. Acute subcortical stroke reached left side corticospinal tracts

**Aim:** To evaluate acutely the remaining capacity of the motor tracts and to follow-up intensive rehabilitation of leg functions



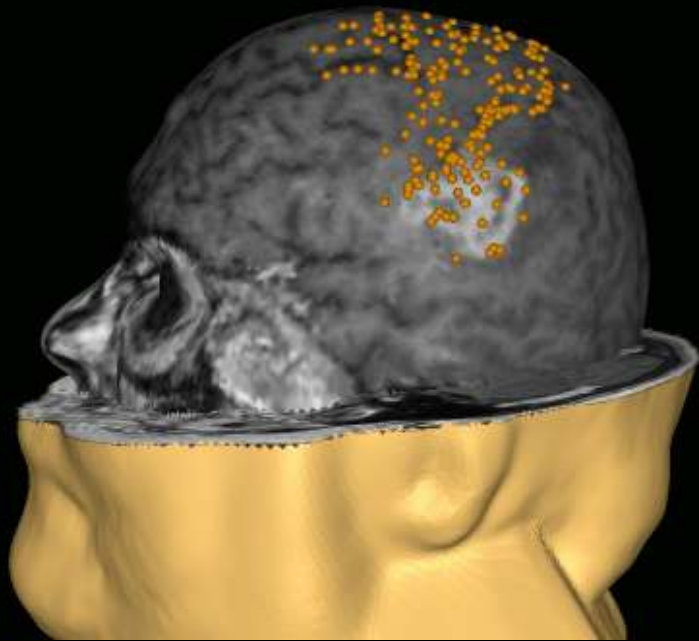
## 2. Evaluation of functional changes in brain after stroke



- Localization of functionally impaired area after stroke -

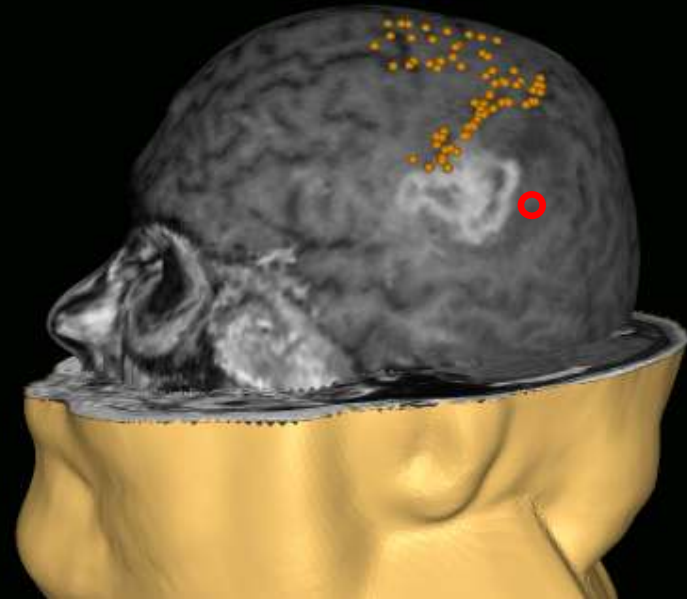
### 3. Planning of tumour resection

stimulated targets



1. EMG-response detected (yellow dot)

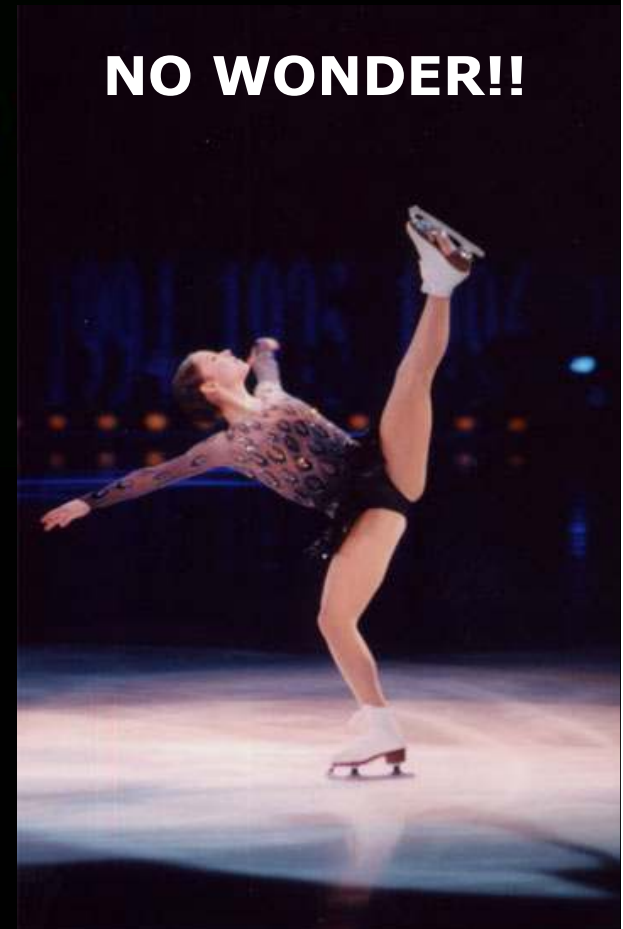
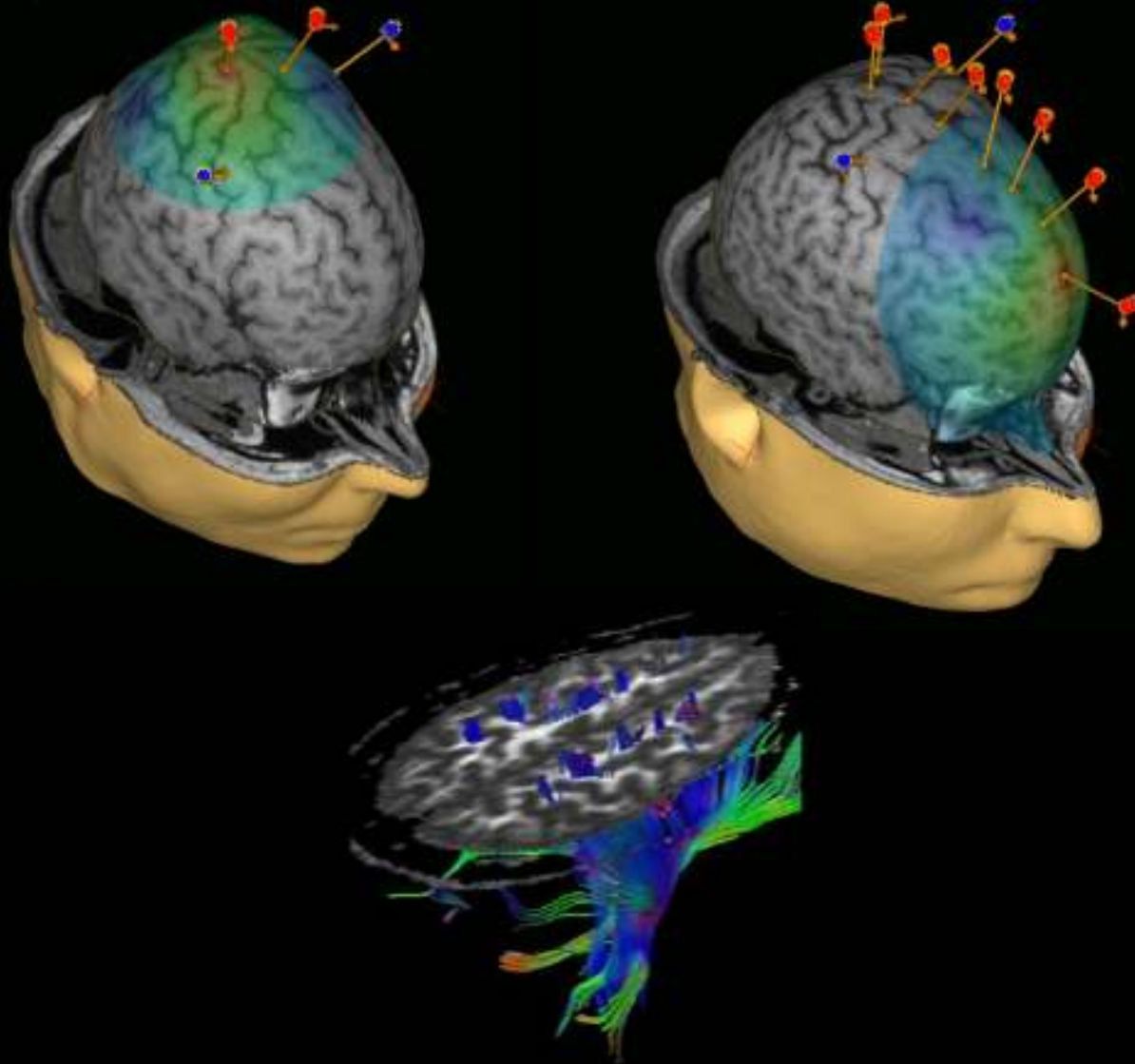
2. Speech distortion (red circle)





## 4. Investigation of training induced changes in motor cortex

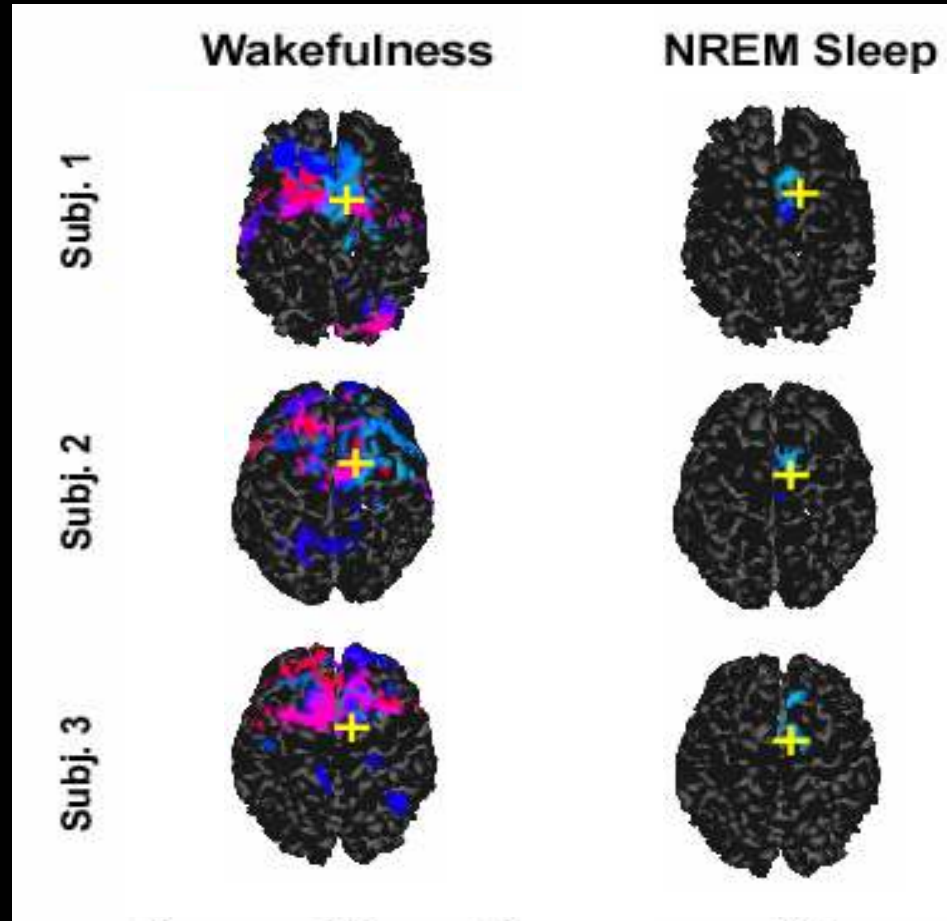
### SPREADING OF LEG REPRESENTATION AREA IN A SKATER



## 5. Investigation of cortical connectivity

### Breakdown of Cortical Effective Connectivity during Sleep

Massimini M, Ferrarelli F, Huber R, Esser SK, Singh H, Tononi G.  
Science. 2005 Sep 30;309(5744):2228-32.



**”The fading of consciousness during certain stages of sleep may be related to a breakdown in cortical effective connectivity”**

## 6. Therapeutic possibilities

Navigated magnetic stimulation has been suggested to have therapeutic potential in:

### 1. Treatment of drug-resistant depression:

“rTMS of the left dorsolateral prefrontal cortex might become a safe, non-convulsive alternative to electroconvulsive treatment in depression”

*Pascual-Leone A, Rubio B; Pallardo F; Catala, MD. Rapid-rate transcranial magnetic stimulation of left dorsolateral prefrontal cortex in drug-resistant depression. Lancet 1996; 348:233-237*

### 2. Neuropathic pain:

“Prolonged and significant pain relief can be achieved with repetitive TMS”

*S Owen and T Z Aziz: Long lasting antalgic effects of daily repetitive transcranial magnetic stimulation in neuropathic pain Journal of Neurology Neurosurgery and Psychiatry 2005;76:761*

### 3. Tinnitus:

“Stimulation of left temporoparietal cortex significantly reduced tinnitus”

*Plewnia C, Bartels M, Gerloff C.:Transient suppression of tinnitus by transcranial magnetic stimulation. Ann Neurol. 2003 Feb;53(2):263-6.*

# To conclude, NBS may be useful...

- **When diagnosing ...**
  - Offers a way to detect and quantify early, non-structural changes
- **When starting the treatment ...**
  - Can help to select the optimal therapy
- **While recovering ...**
  - Allows monitoring of the recovery and plasticity
- **Therapy ...**
  - Neuropathic pain, tinnitus, auditory hallucinations, depression



*Touch the brain without invasive wires and electrodes!*





**Any questions!**