FMRI – DIFFICULTIES IN MIND READING

- fMRI: functional (nuclear) magnetic resonance imaging
- Neuroimaging: get the structure of the brain
  - Want to know how it works: connection brain parts and brain functions
  - Aim: measure the local „thinking activity”
- Usage (criticism):
  - Lie detector
  - Neural- and psychological-modell checking (think/know experiment)

How we use it

- Human attempts frequent
- Well-planned tasks or questions
- Measures: order of minutes
  - One measure: order of 5 seconds
  - Measure with and without tasks or question, further investigation based on the difference
- Overlap the intensity map and brain image

The basics of fMRI

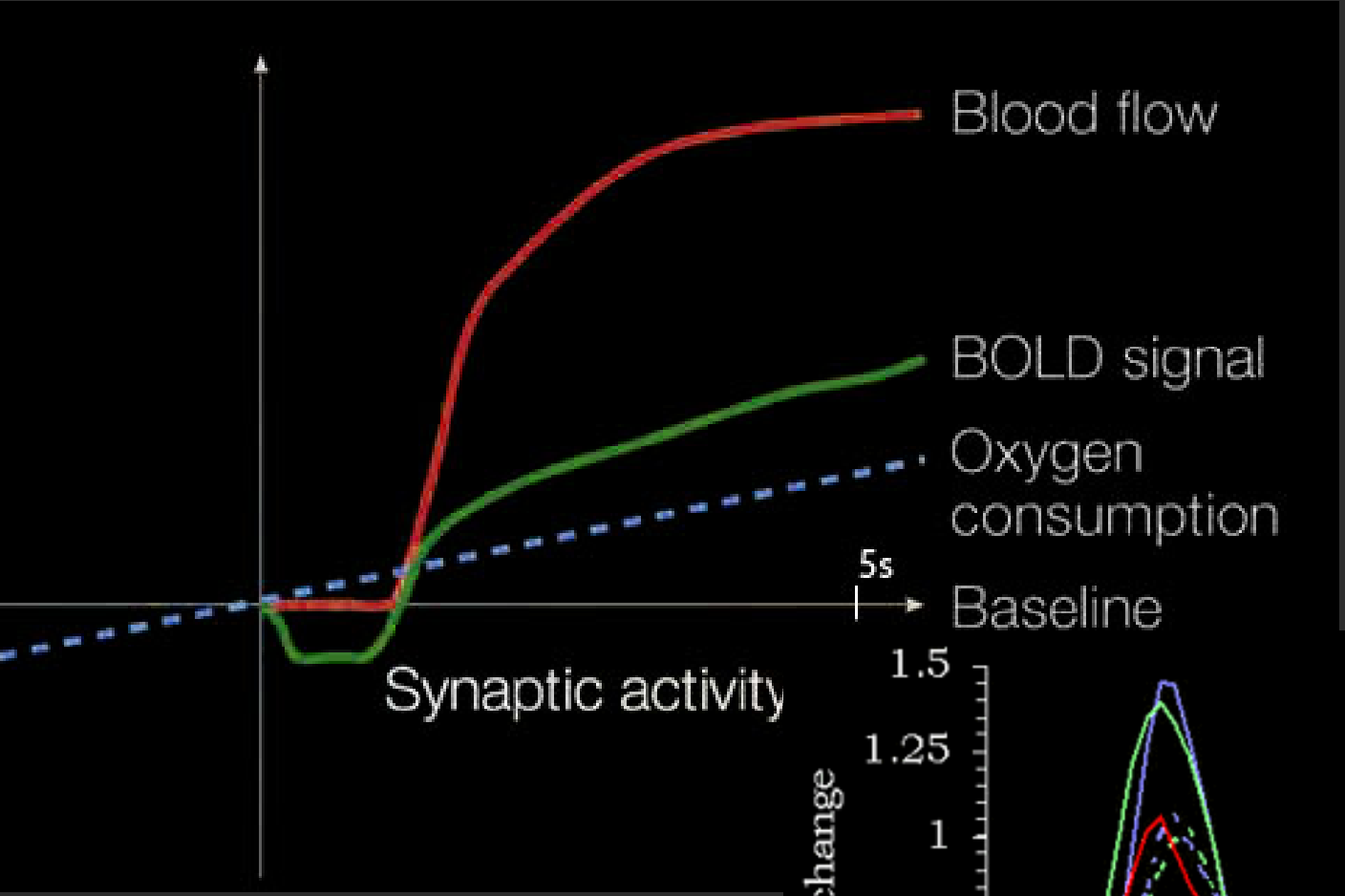
- MRI: interaction between spins and magnetic field
- QM based phenomena
  - Classical view is almost satisfactory
- Find a „think-activity”-sensitive MRI measureable quantity, measure it, and then reflect to think activity

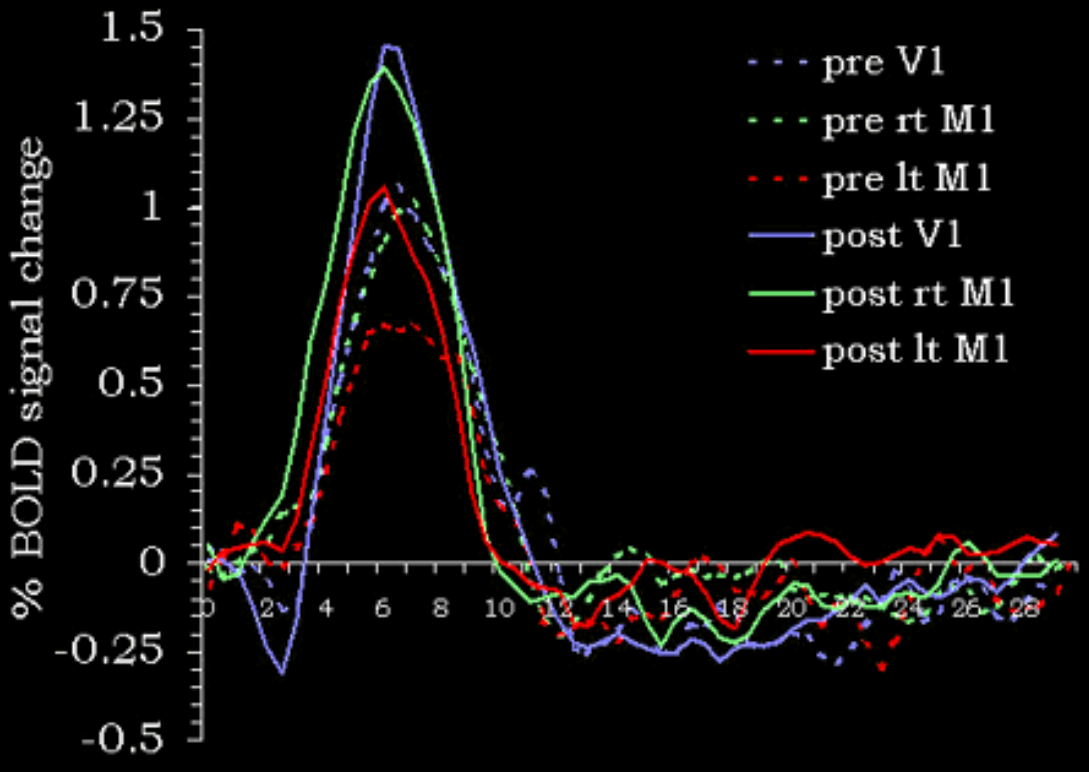
Get the signal - BOLD

- Blood-oxygen-level dependence
- Hemoglobin: Fe^{2+} can absorb O_2
  - Hemoglobin + O_2 : diamagnetic molecule
  - Hemoglobin – O_2 : paramagnetic (S=2)
- Measure the oxygen-flow differencies in vein
- Determine the connection between BOLD singal and toughts

Get the signal – O_2 flow

- The oxygen flow depends on the communicating intenstiy
- Communication needs energy
  - Neuron cells don’t have repository
  - Increased activity needs more energy
  - BOLD signal decreasing and then increasing


Blood flow
BOLD signal
Oxygen consumption
5s
Baseline
Synaptic activity


% BOLD signal change
1.5
1.25
1
0.75
0.5
0.25
0
-0.25
-0.5
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
pre V1
pre rt M1
pre lt M1
post V1
post rt M1
post lt M1

Time, accuracy and resolution

- Time: depends on the BOLD signal, about less than half a minute
  - Do experiments with the same patient, same time
- Accuracy: easily detect maximum of BOLD
- Space: resolution: in order of *mm×mm×mm*
  - Problem: the motion of the patient

Increasing space resolution

- No new information with increasing resolution
  - Signal comes from multiple capillars
- Solution: BOLD signal minimum: more localised
  - Longer time or
  - Bigger magnetic field
- No (?) news: cerebral tasks are not well localised

Temporal resolution

- $\Delta x \cdot \Delta y \cdot \Delta z \cdot \Delta t \approx const$
- Increasing time resolution does count
- (more details) **usable image**
- Two tricks to improve:
  - Spin echo – gradient echo
  - EPI: echo planar imaging

Measurement: EOM

- First: apply $\mathbf{B}_0 = \left(0, 0, B_{z,0}\right) \Rightarrow \mathbf{M} = \left(0, 0, M_0\right)$
- Short RF pulse: $\mathbf{B}(t) = B_1 \left(\sin(\omega t), \cos(\omega t), 0\right)$

- $$\frac{d\mathbf{M}}{dt} = \gamma\left(\mathbf{M} \times \mathbf{B}\right) + \left(\mathbf{M}_0 - \mathbf{M}\right)\boldsymbol{\tau}$$
- $$\frac{dM_z}{dt} = \gamma\left(\mathbf{M} \times \mathbf{B}\right)_z + \frac{M_0 - M_z}{T_1}$$
- $$\frac{dM_i}{dt} = \gamma\left(\mathbf{M} \times \mathbf{B}\right)_i - M_i / T_2 \quad i \in \{x, y\}$$

Measurement: relaxation and decoherence

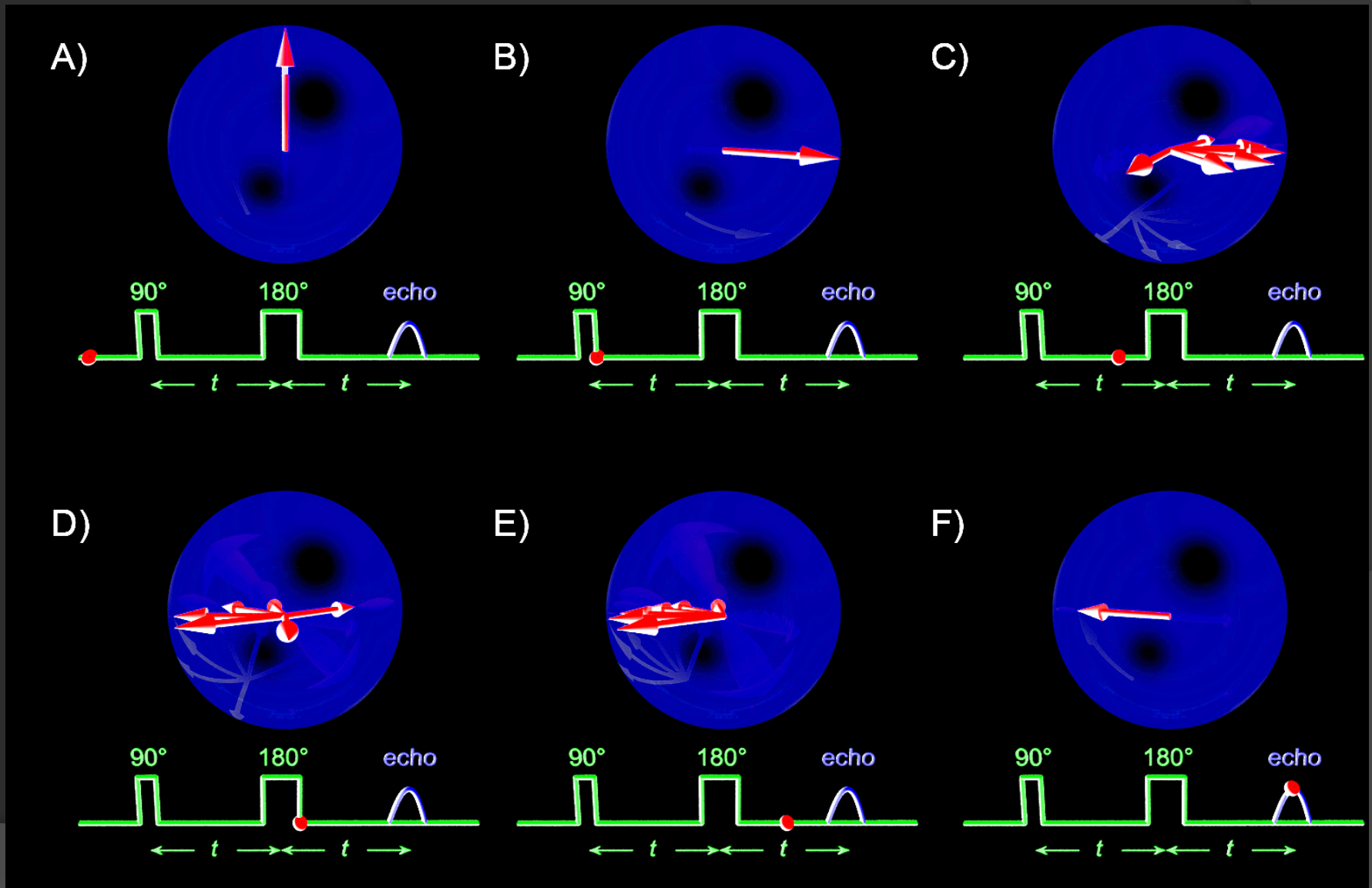
- Solutions after „excitation”: $M_z = M_0\left(1 - e^{-t/T_1}\right)$

$$M_i = M_0 \cdot e^{i\gamma B_0 t - t/T_2} = M_0 \cdot e^{i\omega_L t - t/T_2}$$

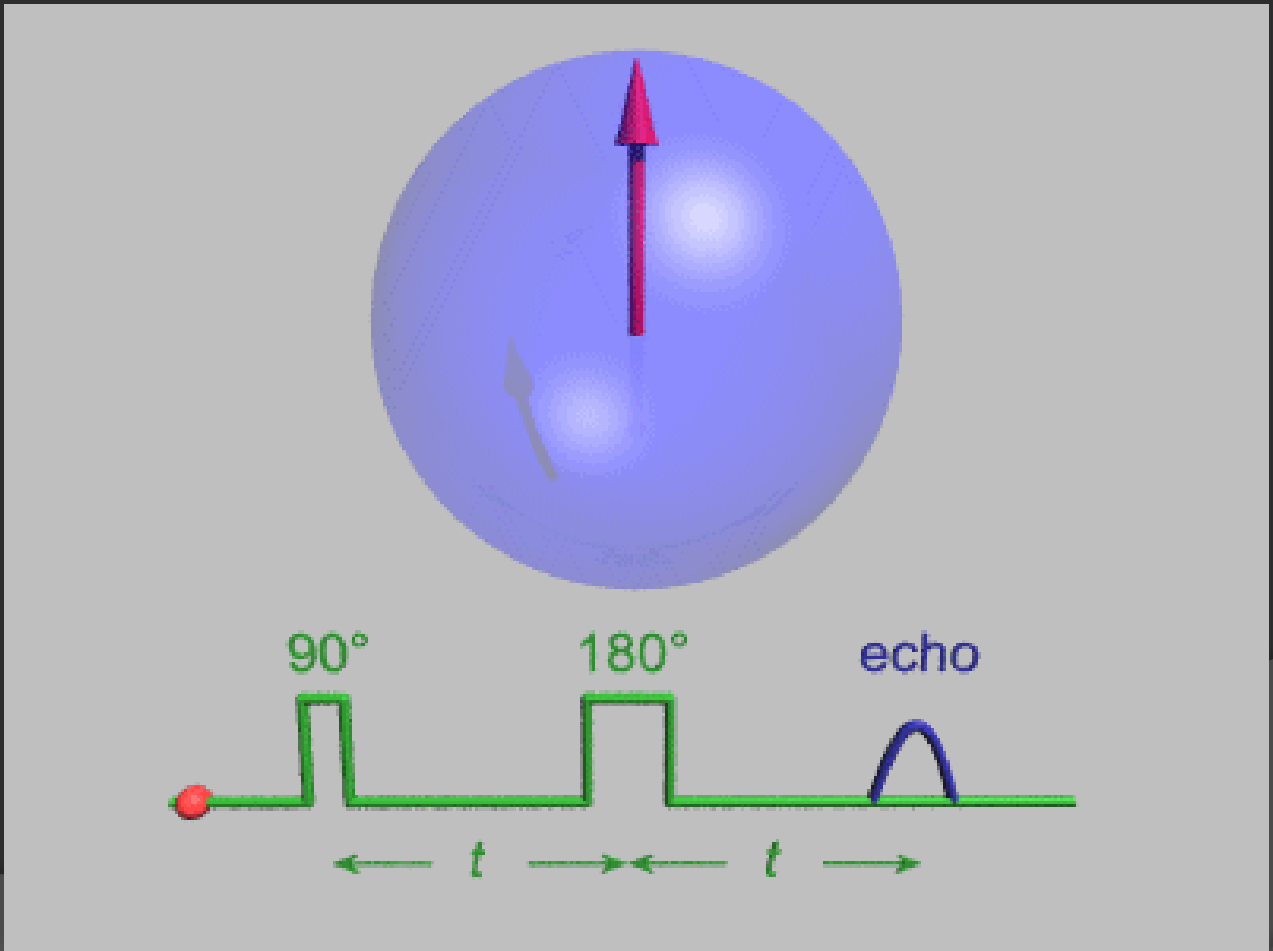
- We can measure M_i

- Important: $T_1 \neq T_2 \quad T_2 > T_1$
- New rotating cylindrical coordinates with frequency: $\omega_L = \gamma B_0$

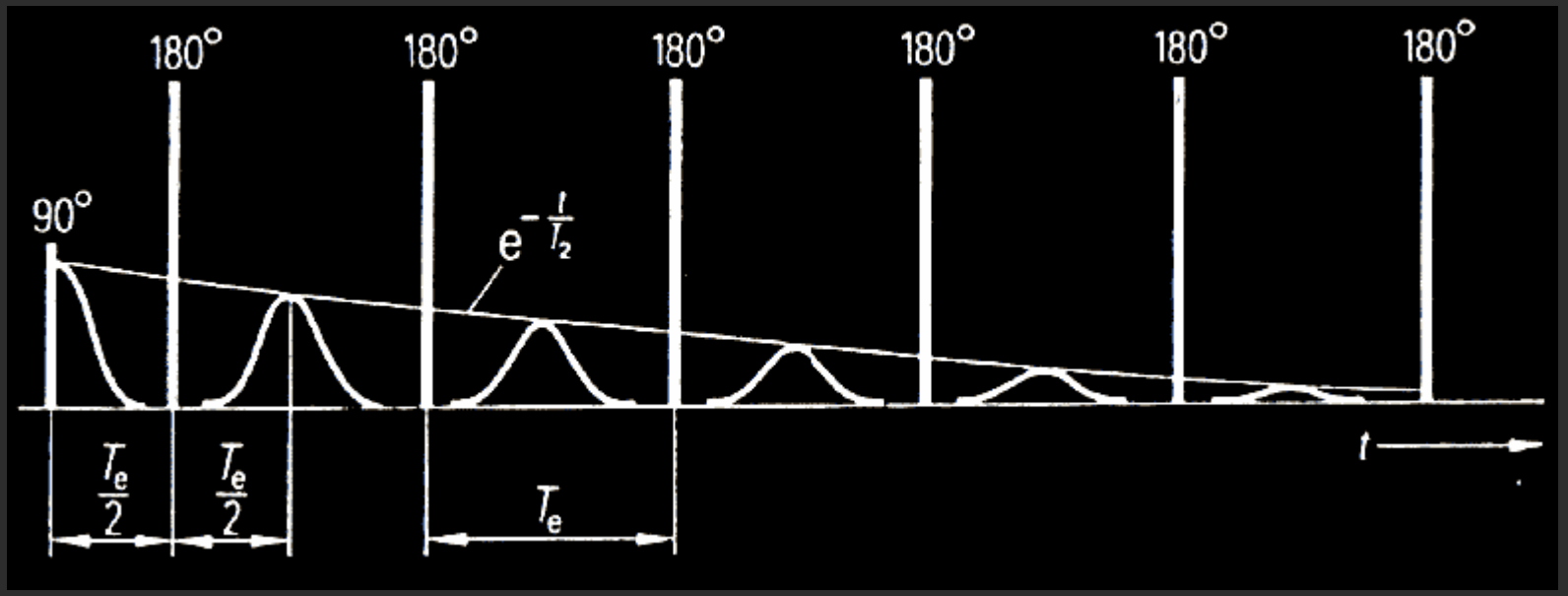
Measurement: spin-echo



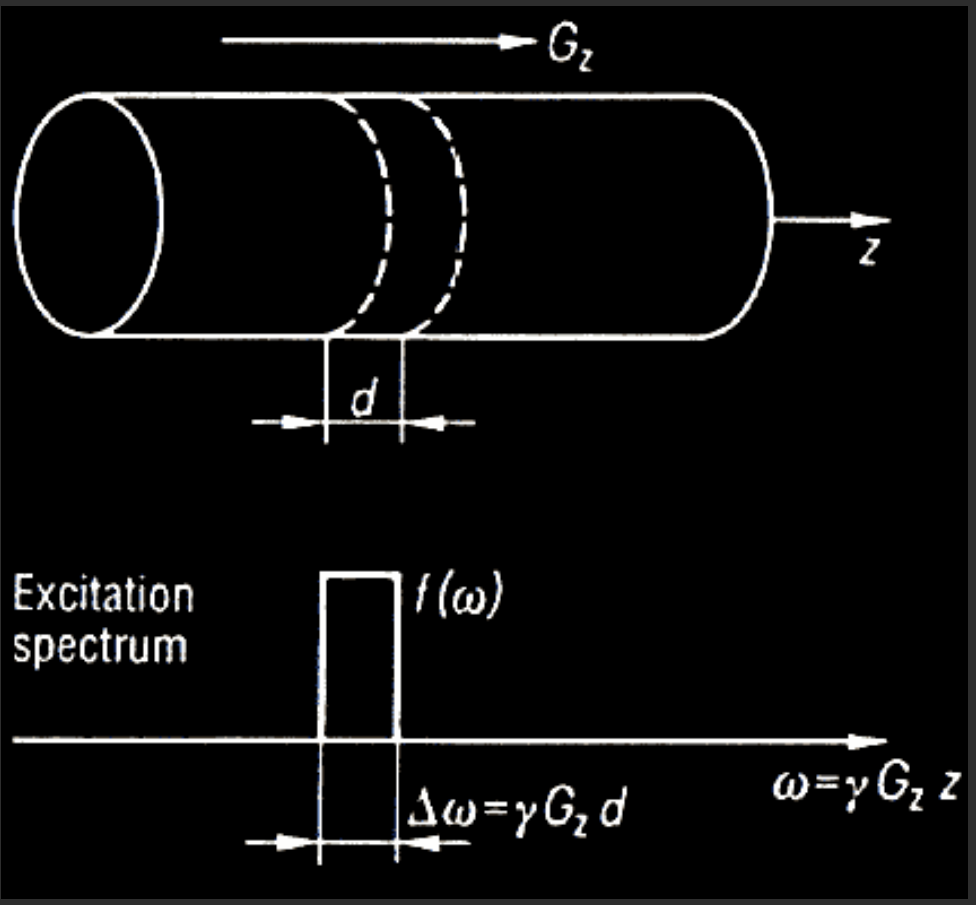
Measurement: spin-echo



Measurement: spin-echo



Measurement: slice-excitation

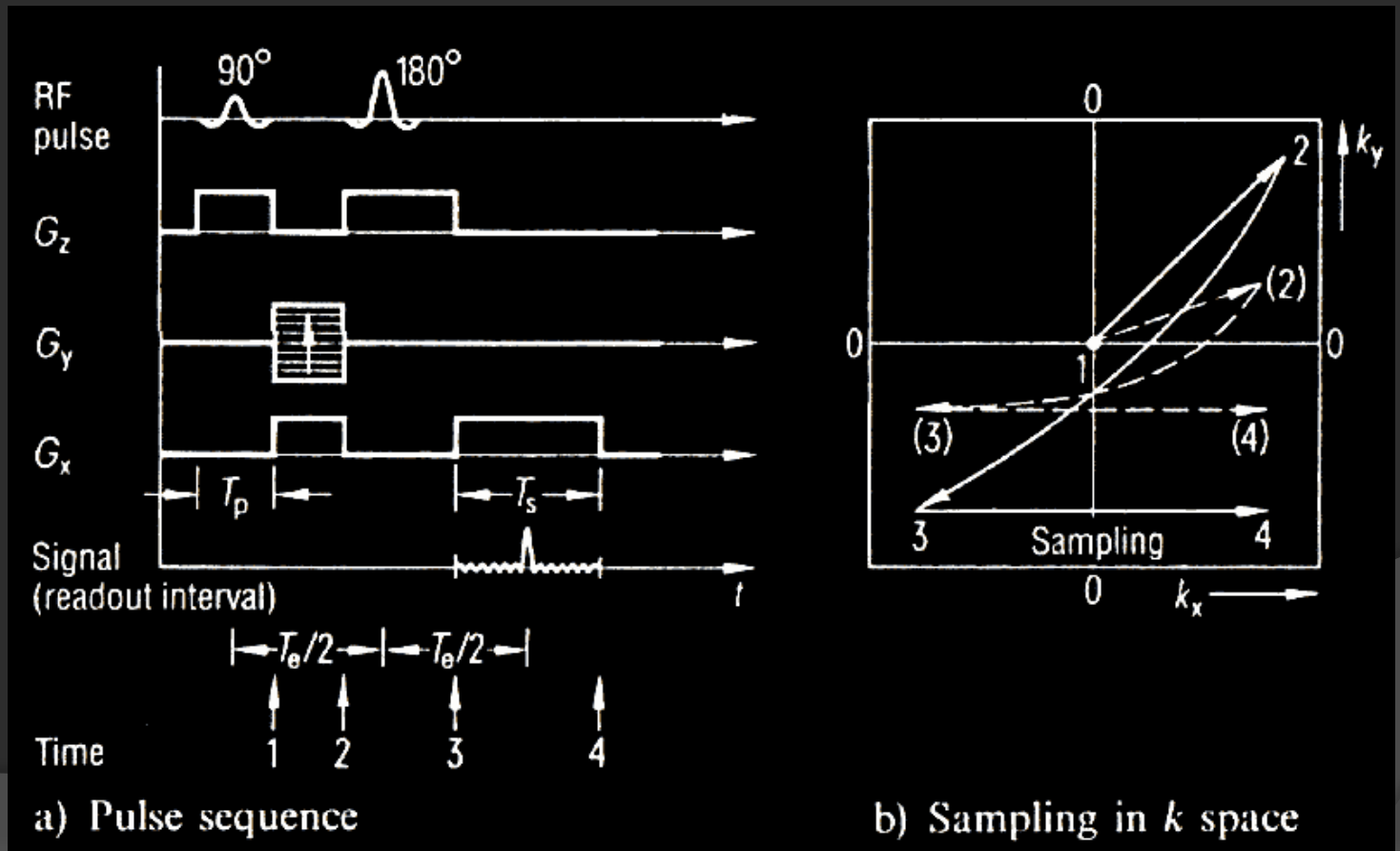


$$\frac{dM_i}{dt}(z,t) = \gamma\left(\mathbf{M}\times\mathbf{B}^*(t)\right)_i \cdot e^{i\gamma(B_0+G_z\cdot z)} = \gamma M_0 B_1^*(t) e^{i\gamma B_0 - i\gamma G_z\cdot zt}$$

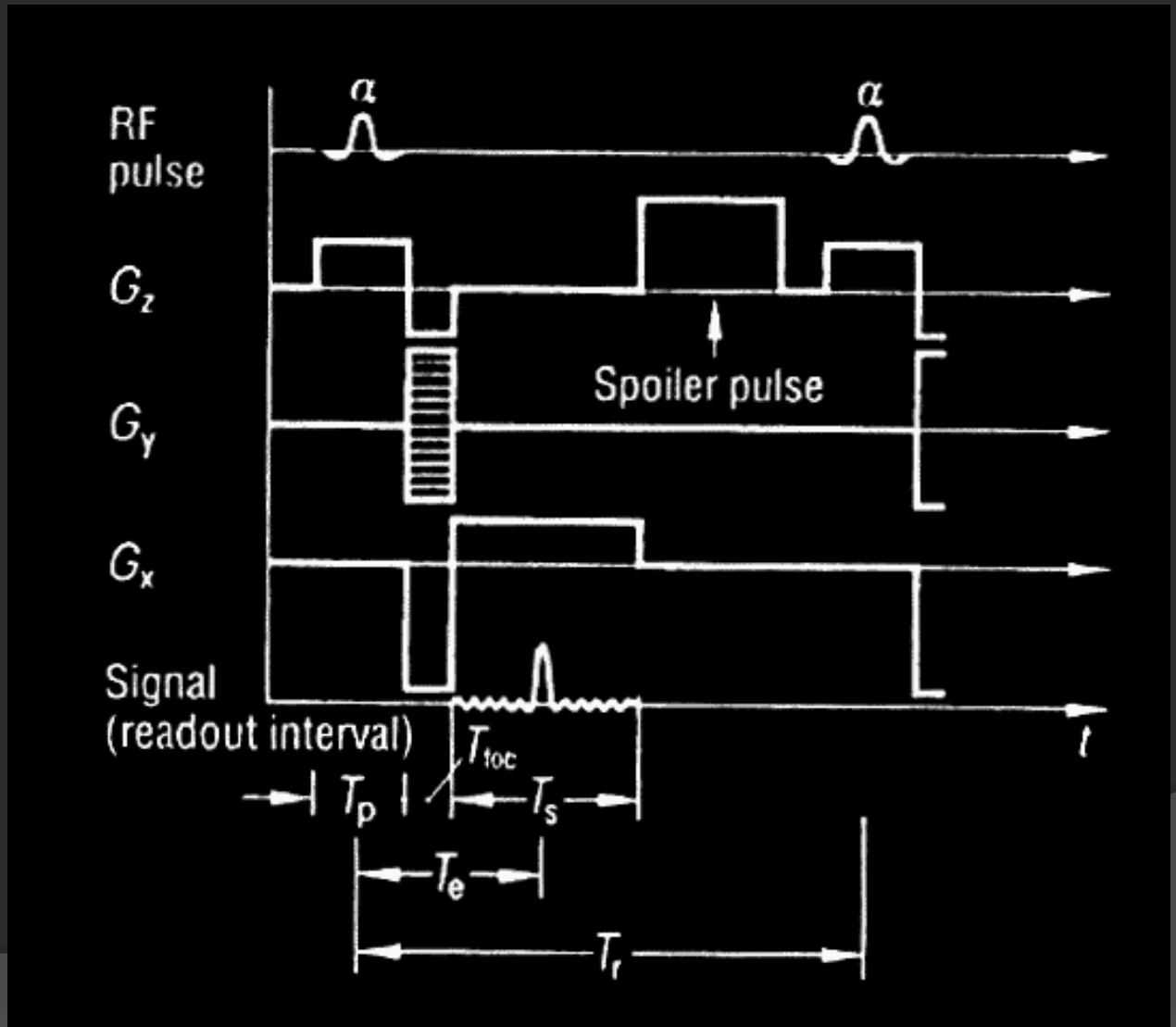
$$\frac{dM_r}{dt}(z,t) = \gamma M_0 \cdot B_1^*(t)\cdot e^{-i\gamma G_z\cdot z\cdot t}$$

Measurement: slice-excitation and spin-echo

- Find $B_1^*(t)$ for the desired excitation-distribution: $B_1^*(t) = B_1 \sin(x)/x \quad x = \gamma G_z d \cdot t$

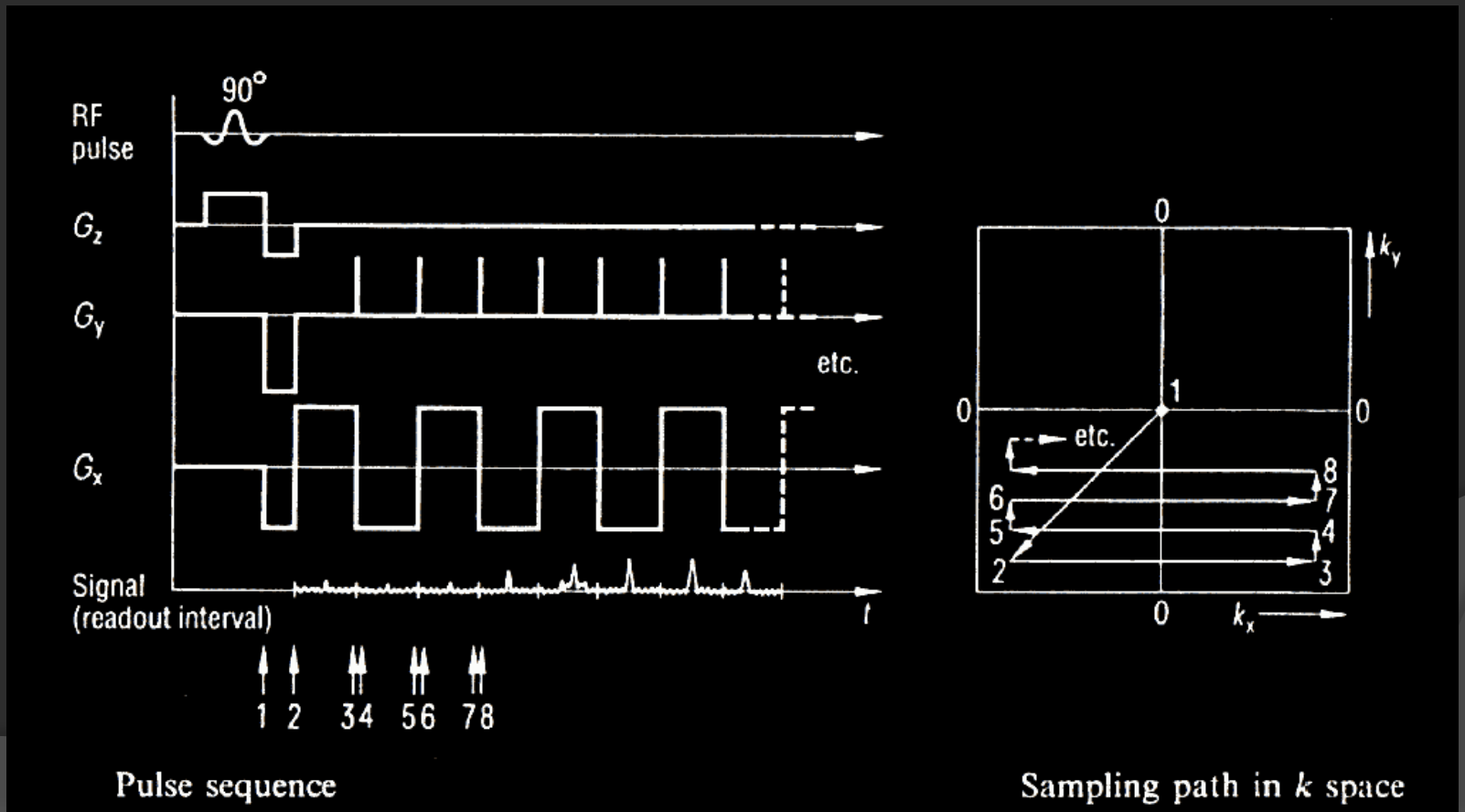


Measurement: another way, the gradient echo

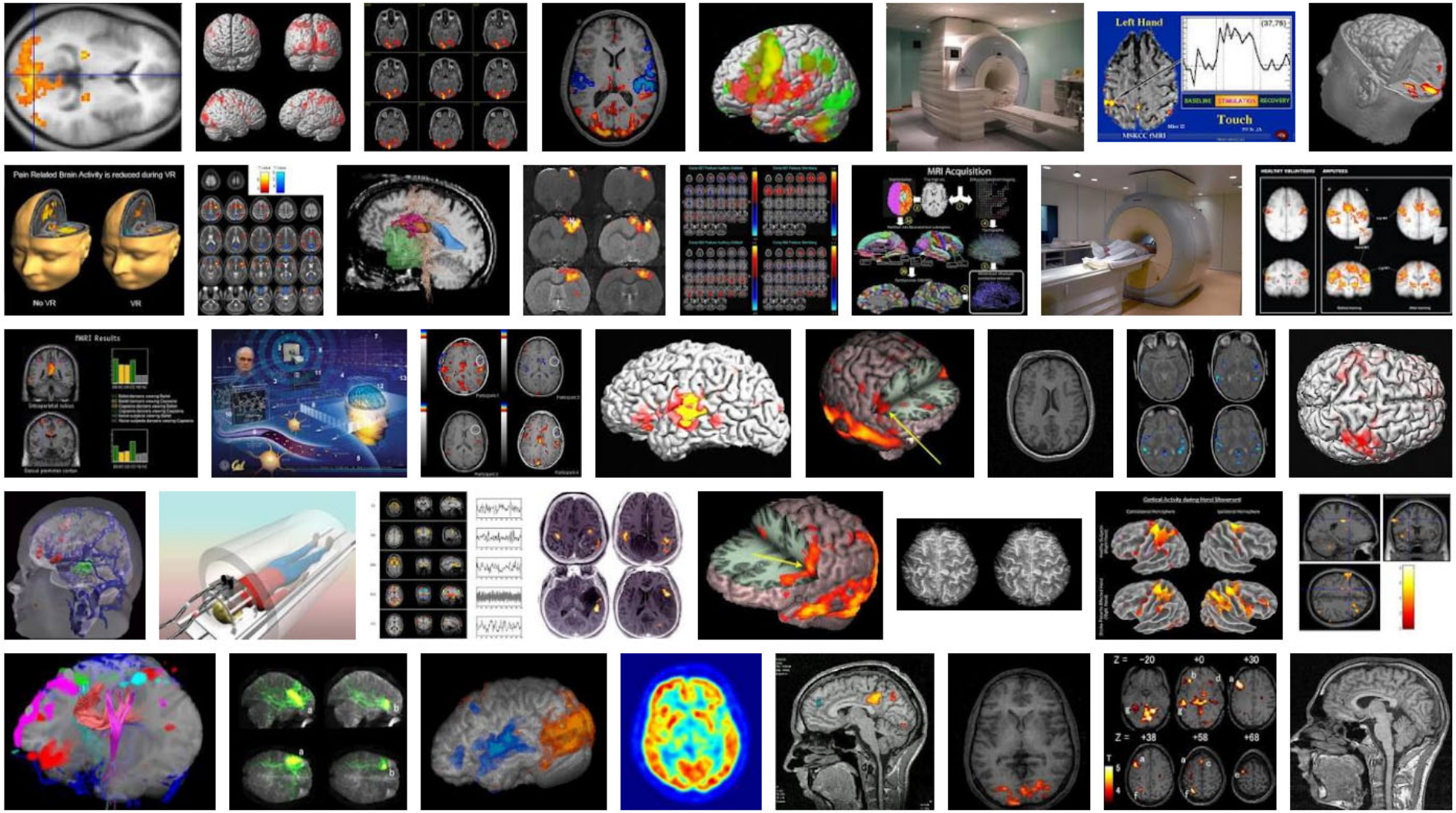


Measurement: EPI

- Echo Planar Imaging: increase time resolution even more!

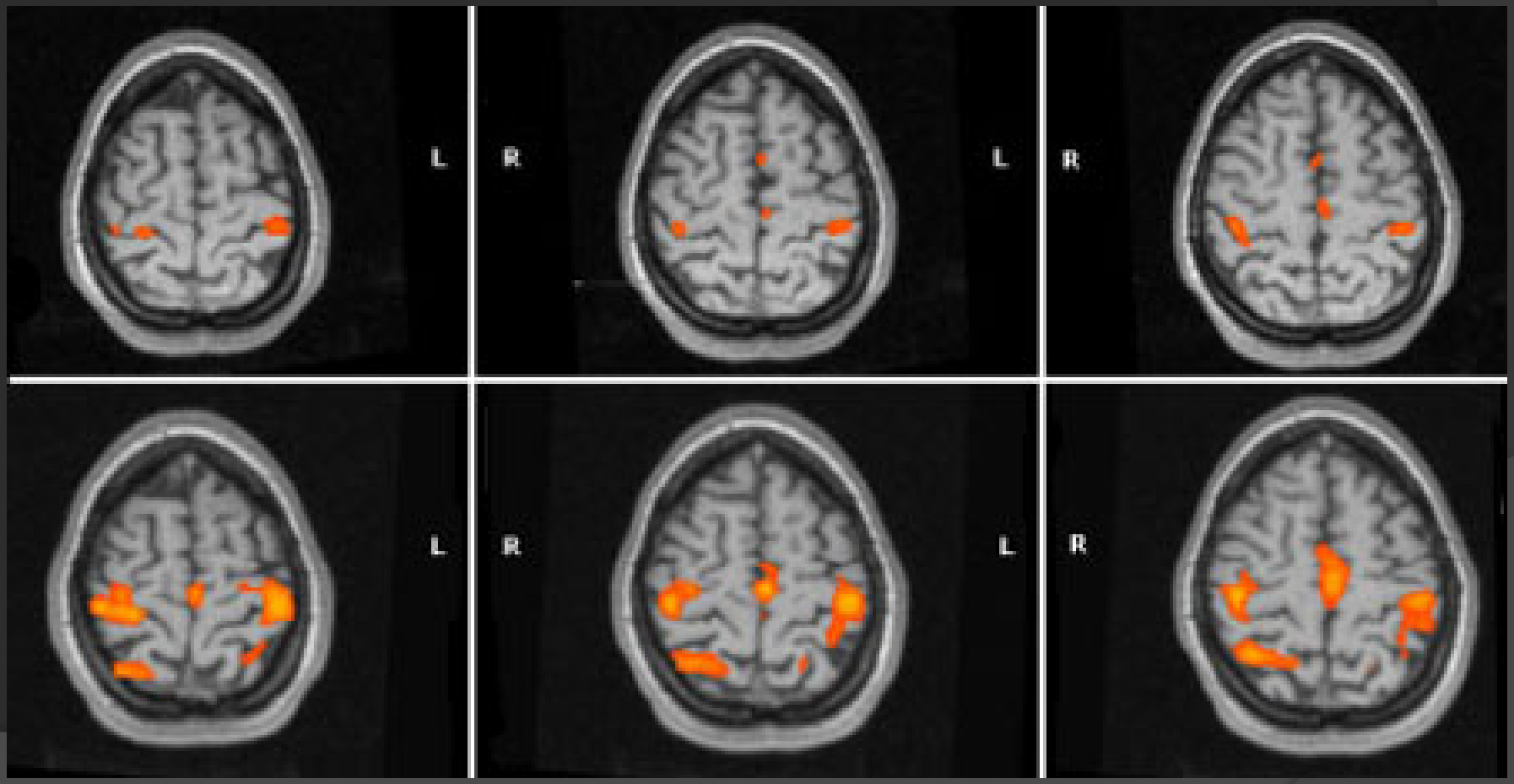


What we get: images



An experiment: caffeine

- **caffeine as a contrast booster**



Limits

- We cannot answer any why question – only answer the question where
- The brain is 3D – the image is 2D, so more experiments needed
- We can measure only the neurons firing, but not the real actyvity (block or stimulate?)
- High degree of cerebral plasticity: places may vary

Mind reading

- The map of optic nerves to vissual cortex is so „localised”, „continous”
- Training set: known videos and those fMRI signal
- Unknown video: fMRI signal → video images
- Ability to guess what patient think
- Numerical problem
- Further aim: movement of implants
- Success: camera-eye

Presented movie

Reconstructed movies (AHP)

Highest posterior movies

S1

S2

S3