FUNCTIONAL MAGNETIC RESONANCE IMAGING (fMRI)

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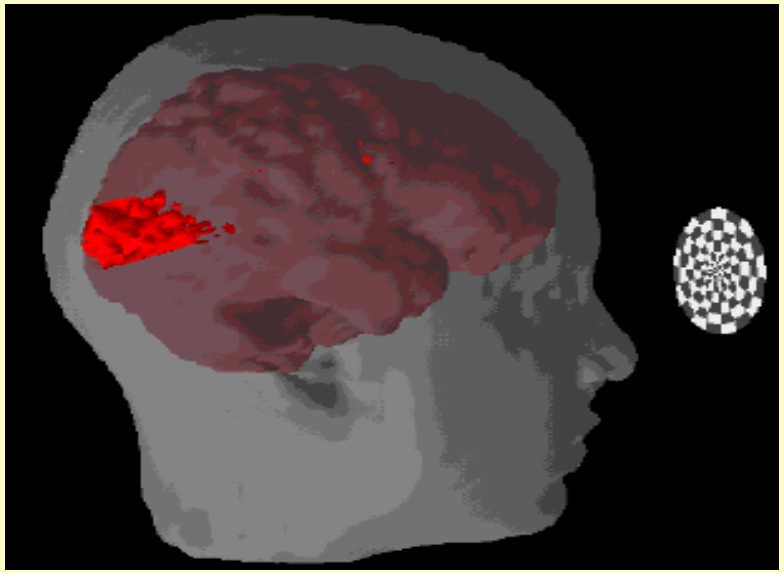
About history of fMRI

- Since 1977 when the first clinical MRI scanner was patented nuclear magnetic resonance imaging is increasingly being used for medical diagnosis and in scientific research and application in practice. In 1992 Ogawa and Turner demonstrated an image contrast by changing oxygenation state of blood and opened a unique method of investigation.

Problem which fMRI's helping to solve

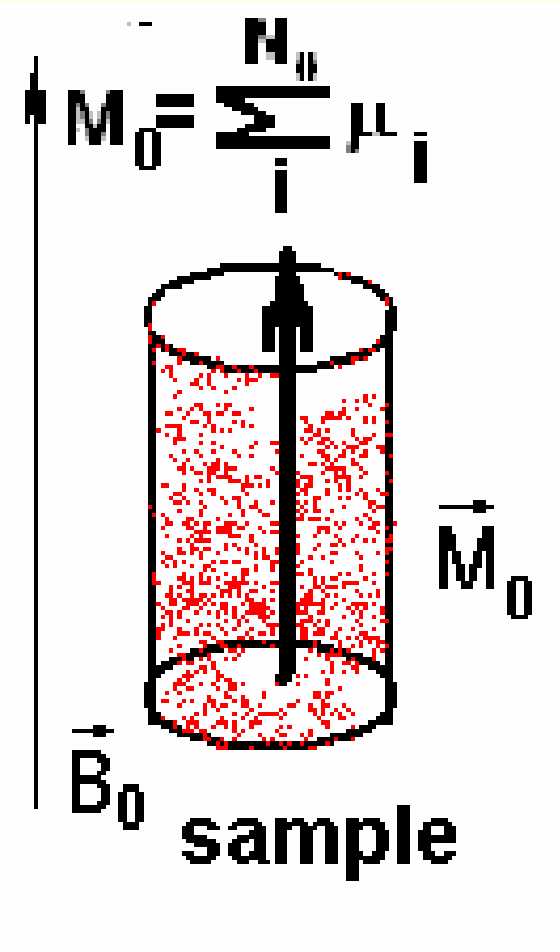


- **The most important role of fMRI in investigating human brain function arises from the fact that brain function is spatially segmented**.

- An important additional feature of fMRI is capability to follow signal changes in real time with a high spatial resolution

The basic principles of NMR

Macroscopic magnetization

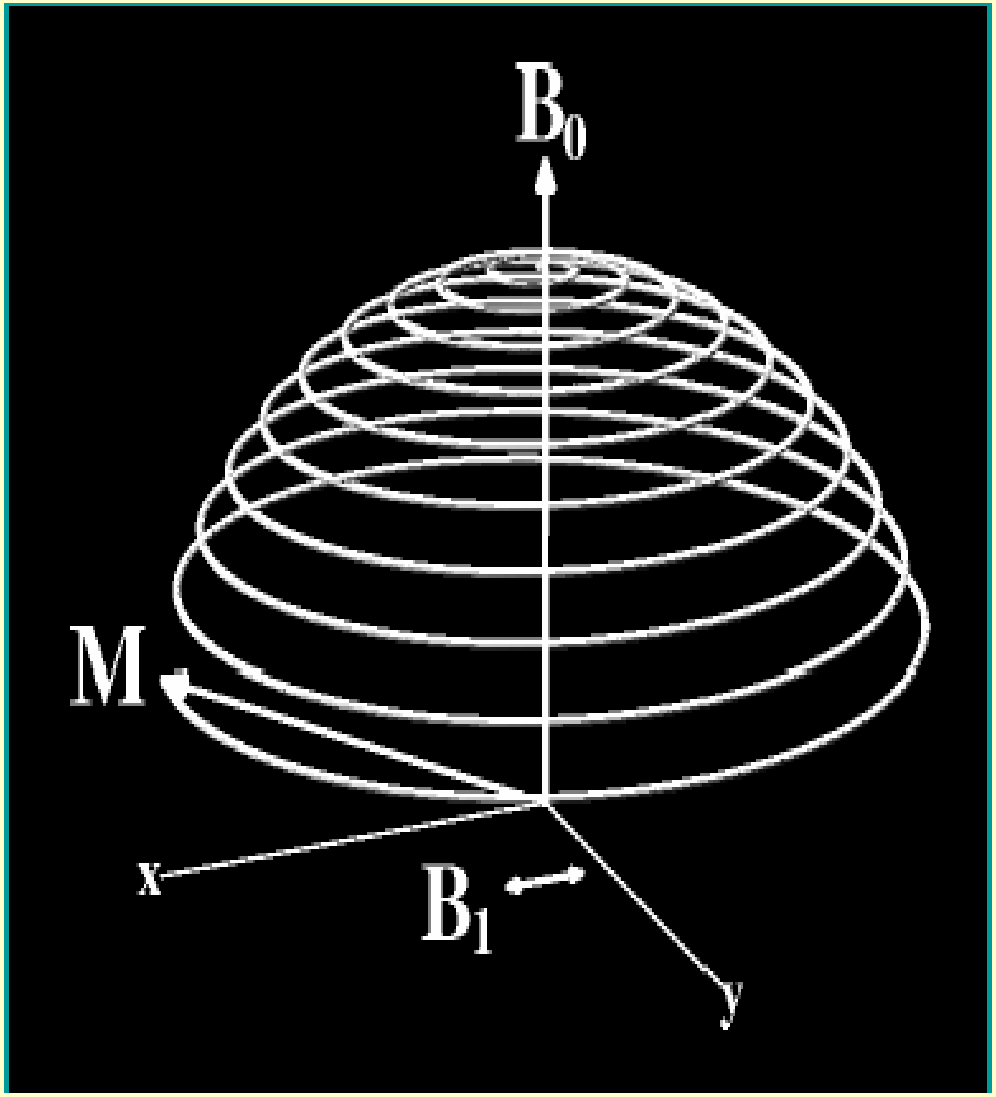


μ_i–magnetic moment of nucleus N I, N_0 – quantity of nuclei in sample

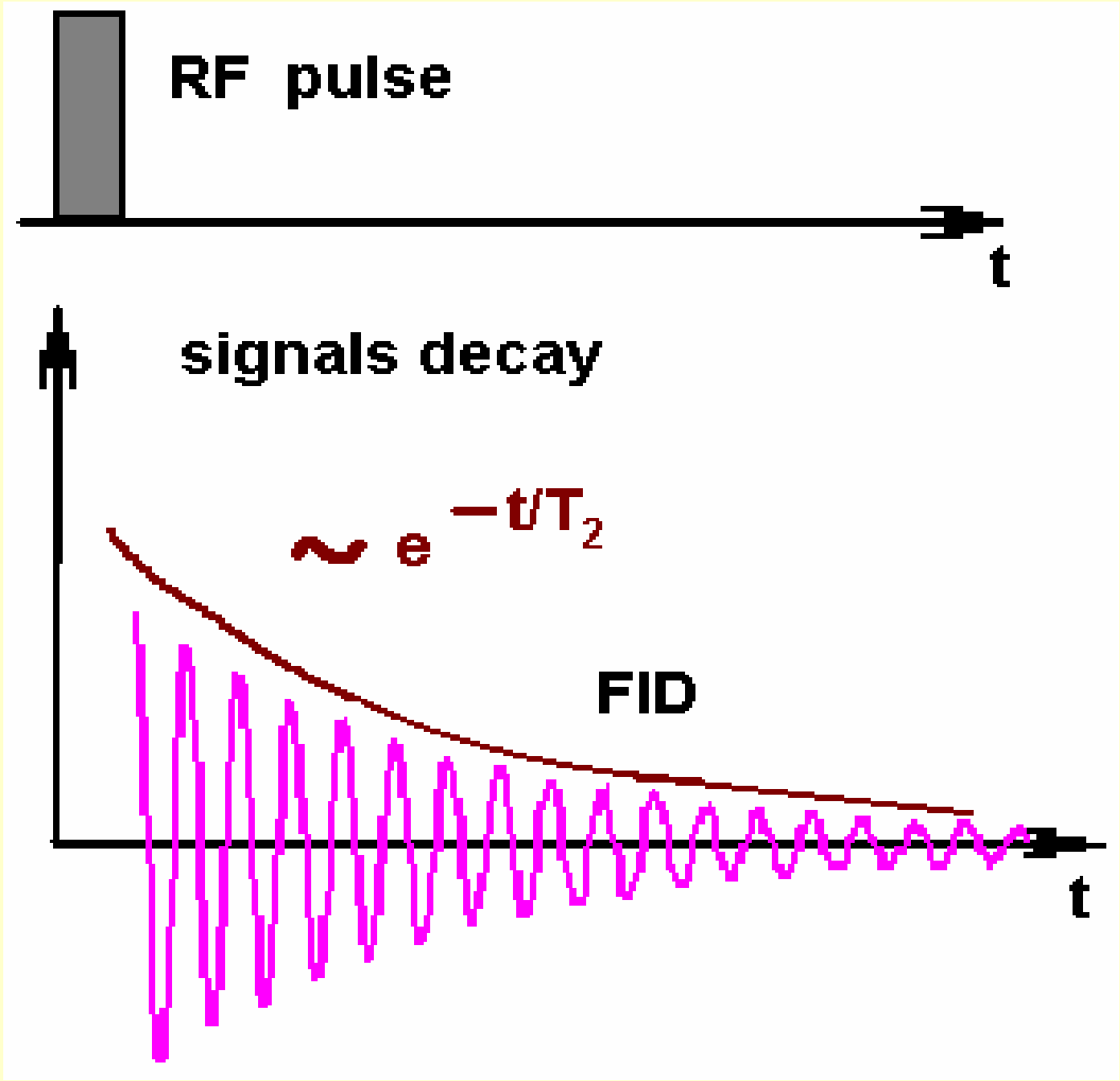
Macroscopic magnetization (M_0) aligns along external field. If M_0 is disturbed from equilibrium frequency of its nutation

Is $\omega = -\gamma B_0$ (Larmor frequency)

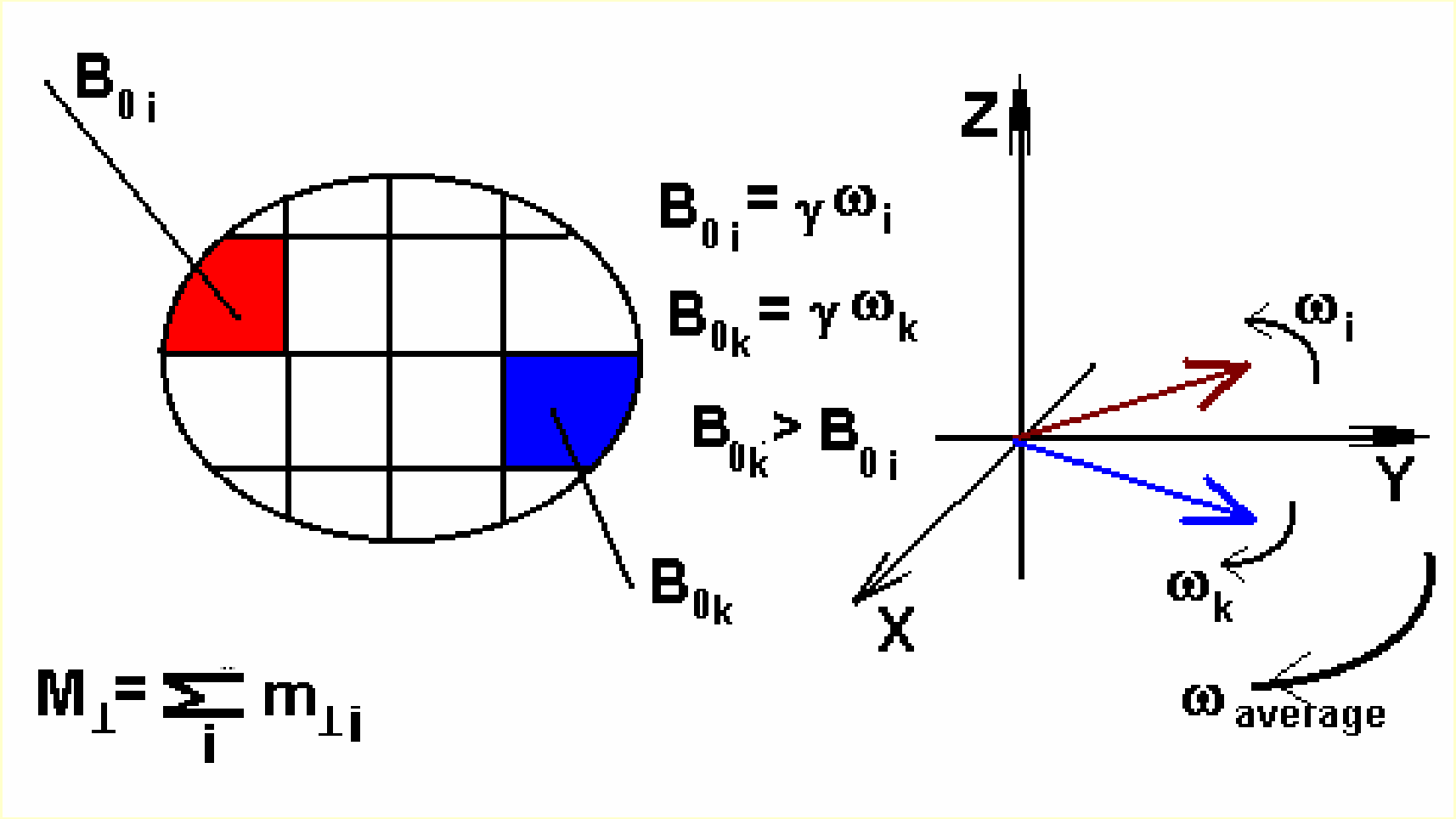
In laboratory frame of refers



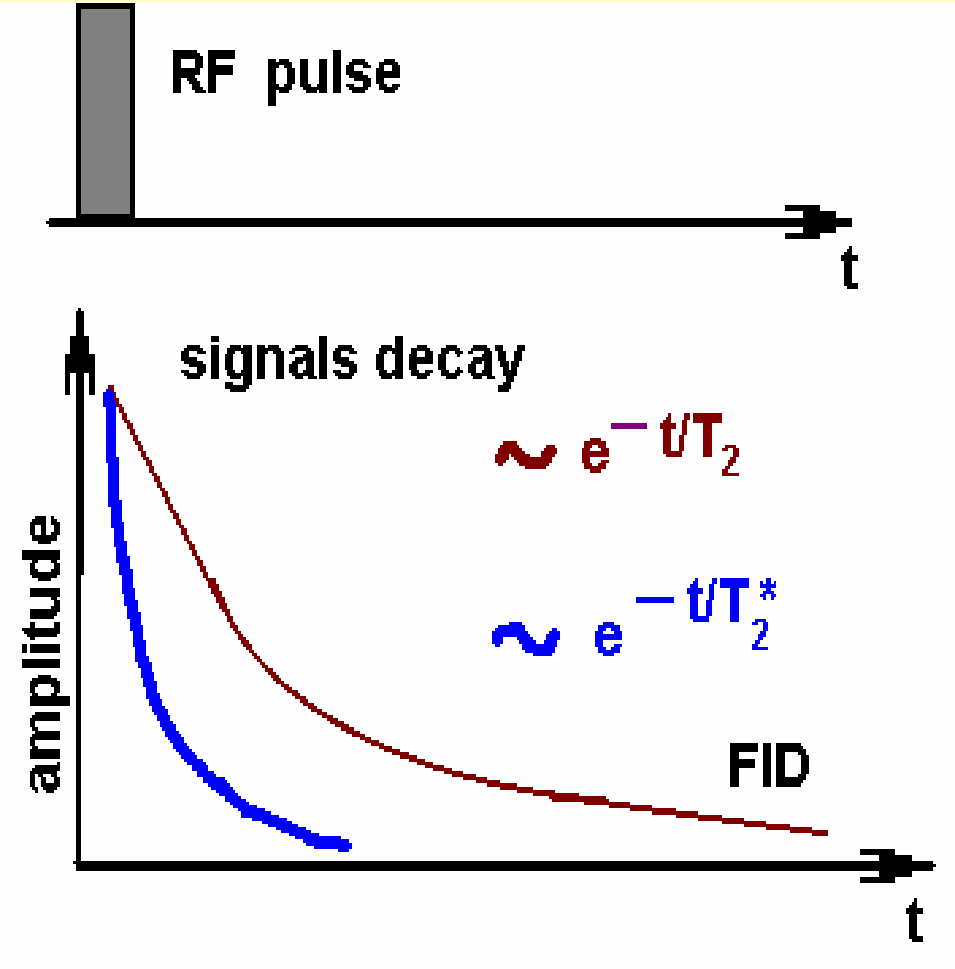
- Exciting 90^0 radio frequency pulse tips M_0 to transverse plane spirals down. $B_1 << B_0$


RF pulse
t
signals decay
$\sim e^{-t/T_2}$
FID
t

Inhomogeneities speed up transversal magnetizations dephasing



T_2^*.

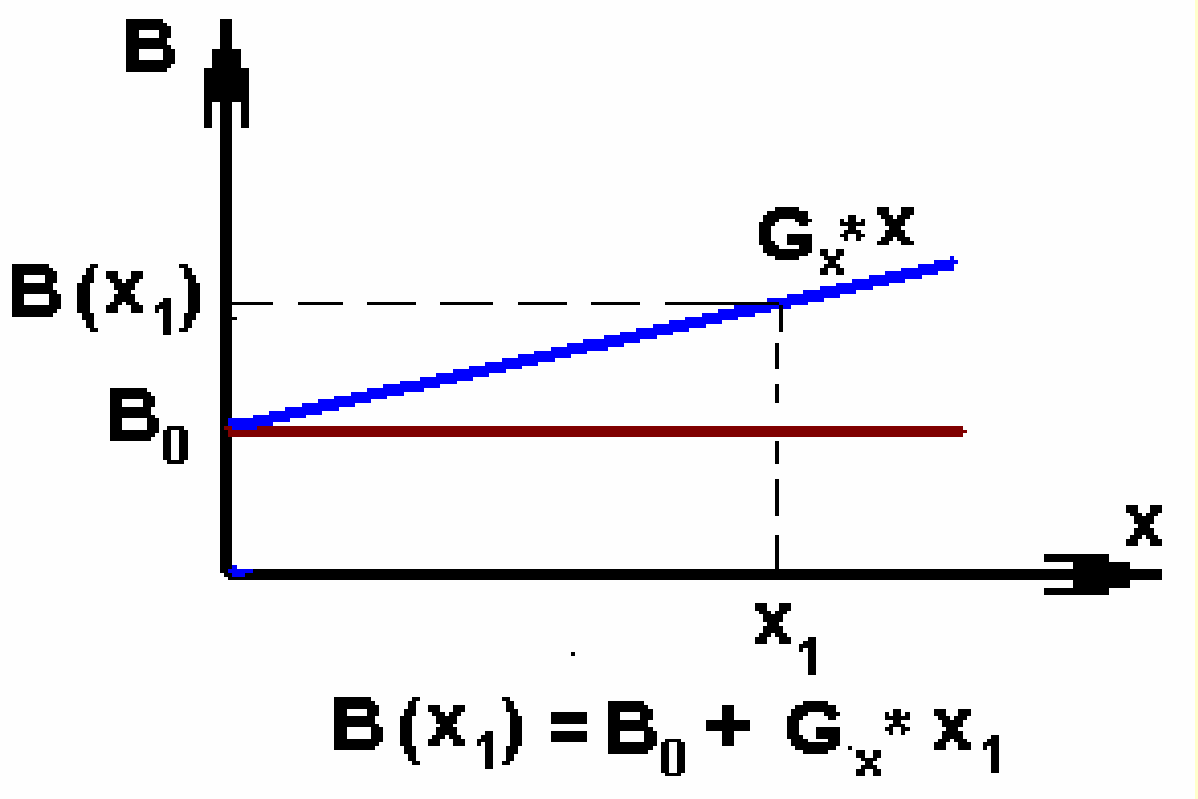


In the present of inhomogeneities of external field signals exponential decay is much faster.

$T_2^* < T_2$

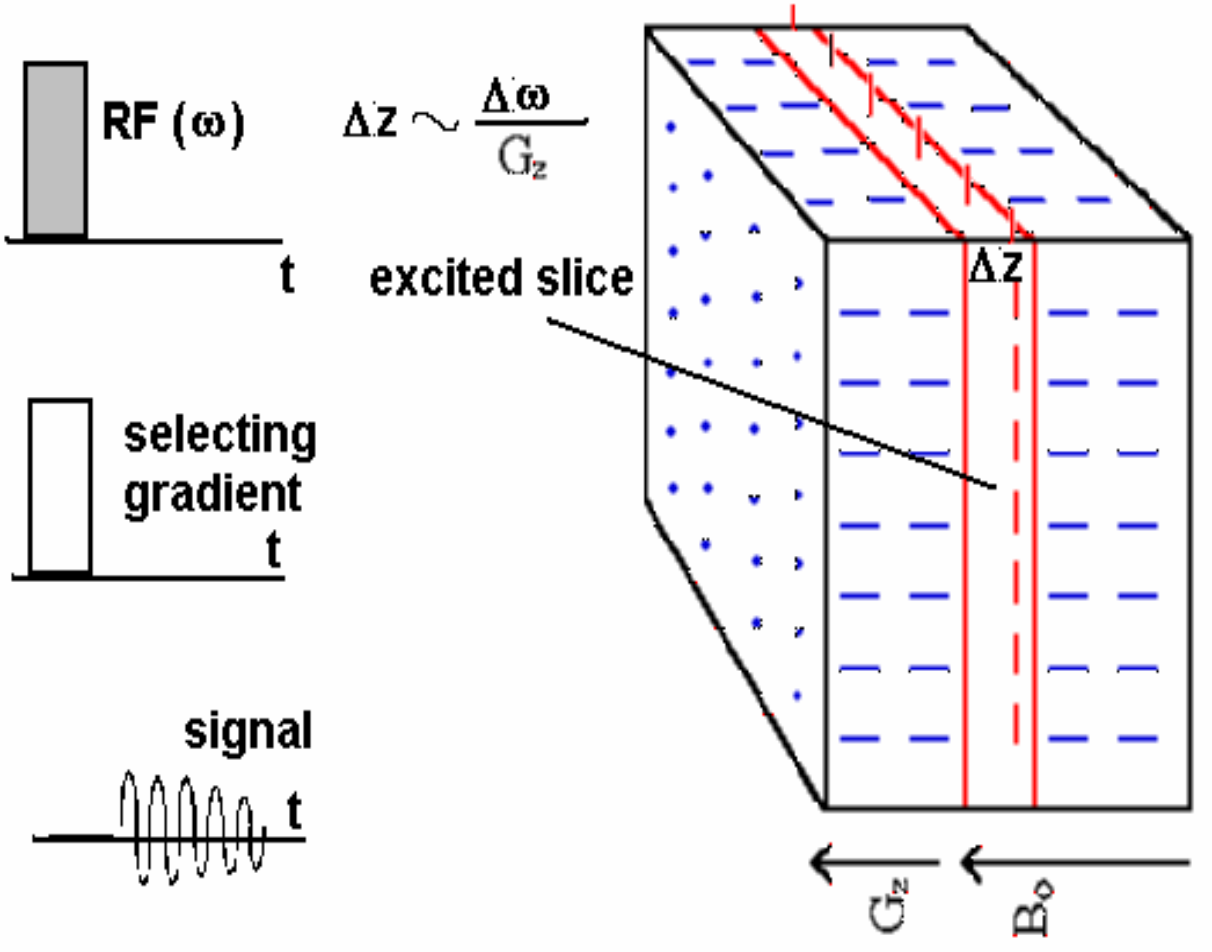
Creation of image

Gradient



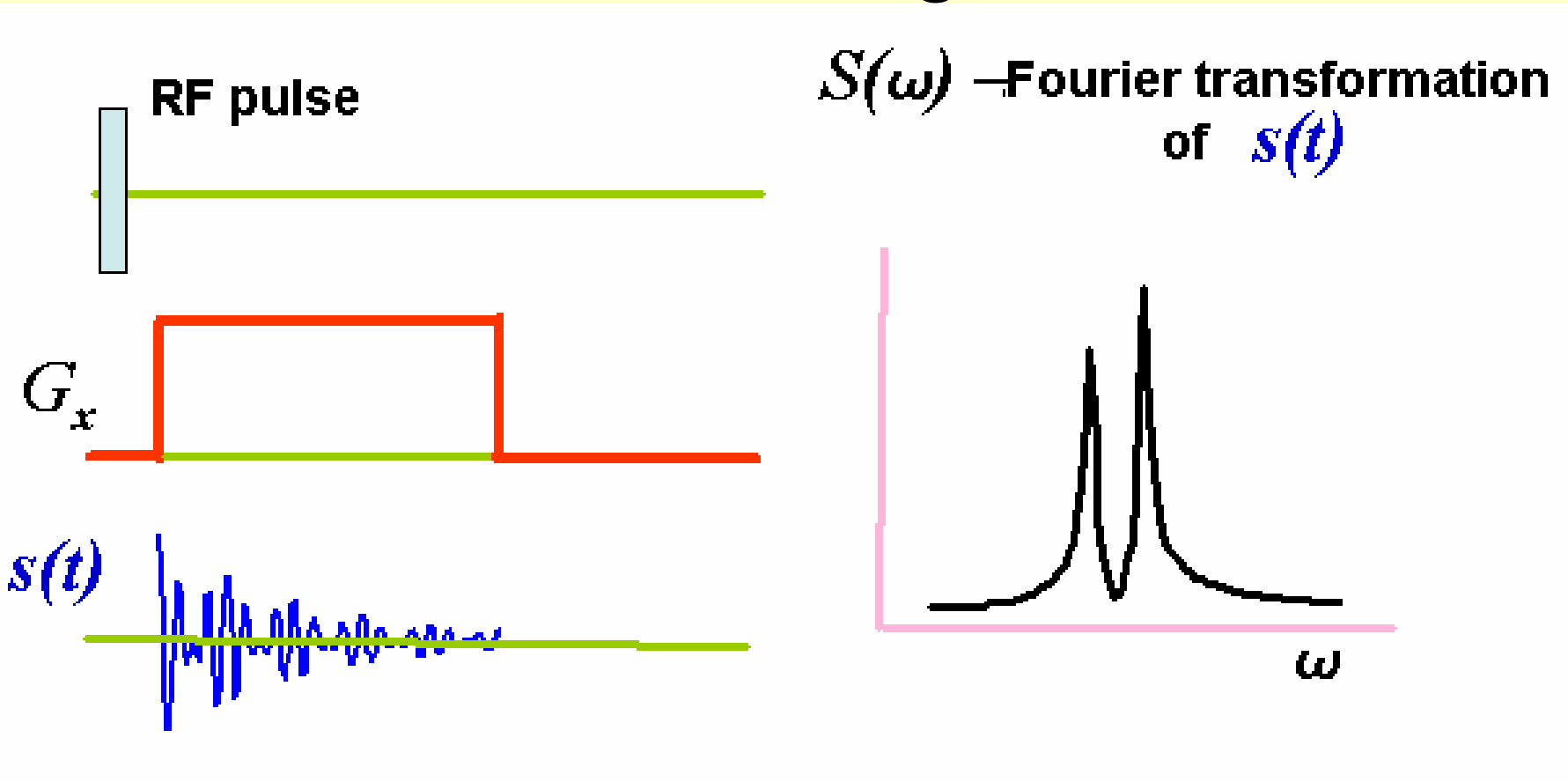
- Gradient is applying magnetic field which value has a linear dependence on coordinate

Slice selection

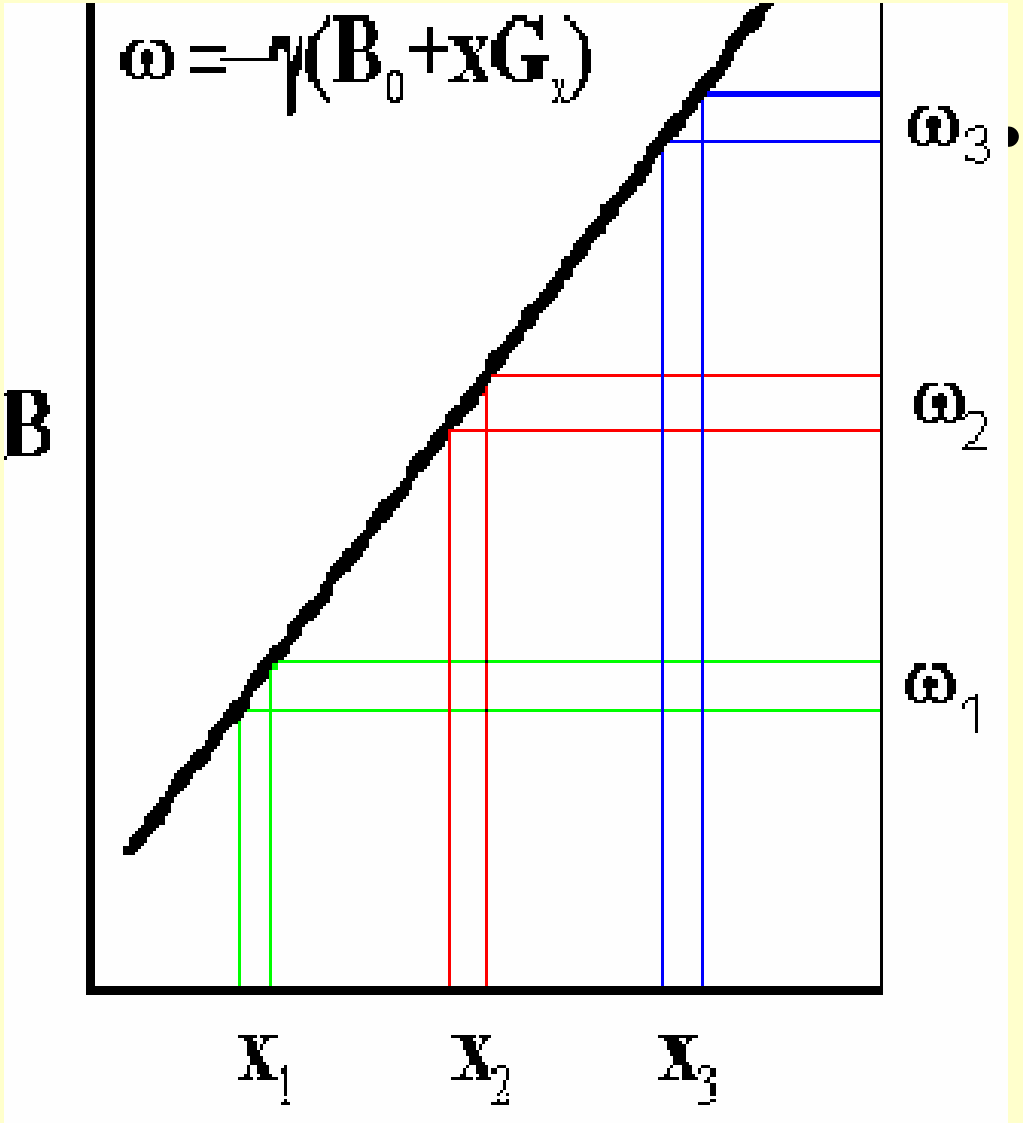


- Due to SG RF pulse excites only spins which Larmor frequency coincides with diapason of pulses frequencies .

Pulse sequence for frequency encoding

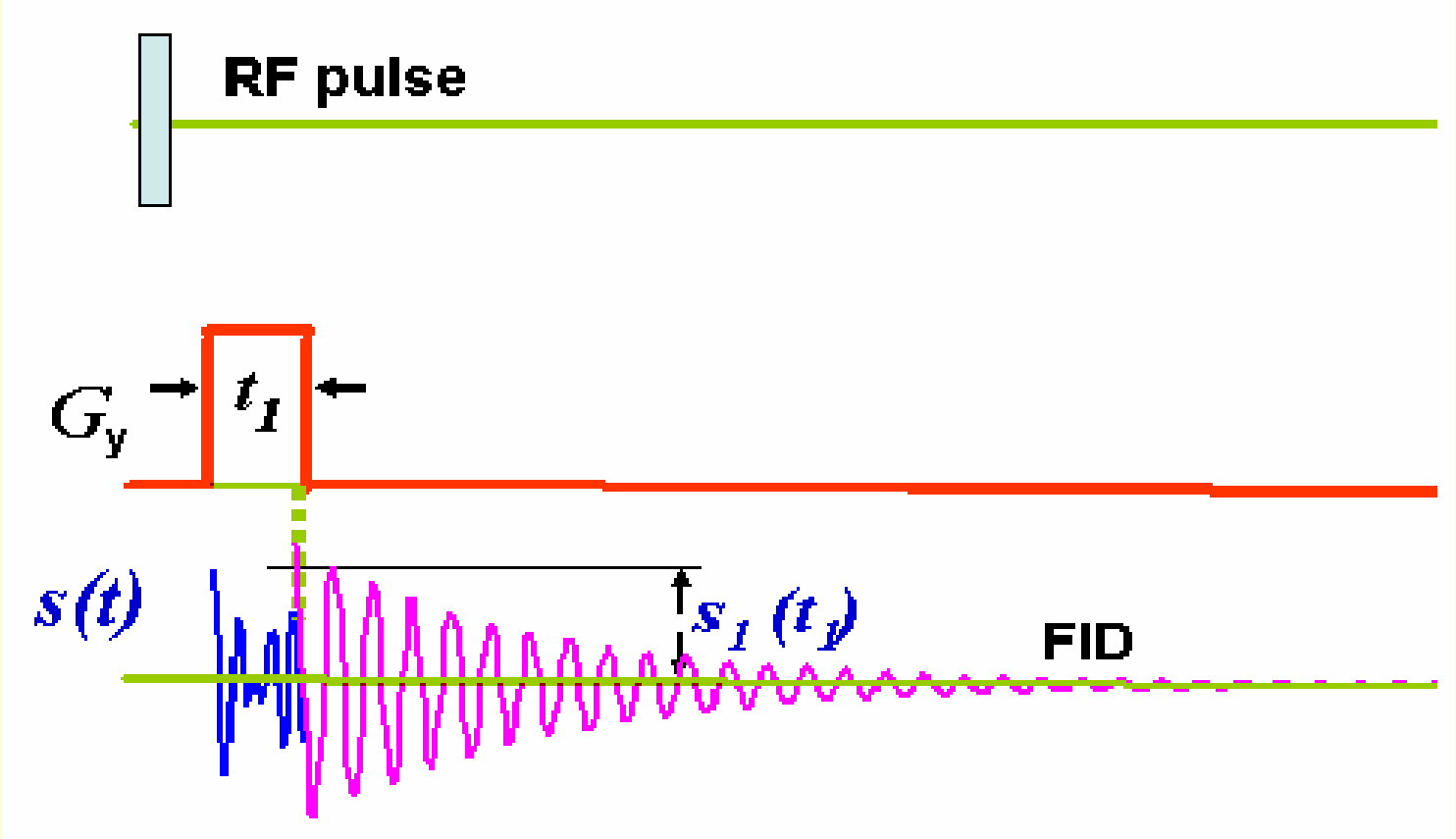


Frequency encoding

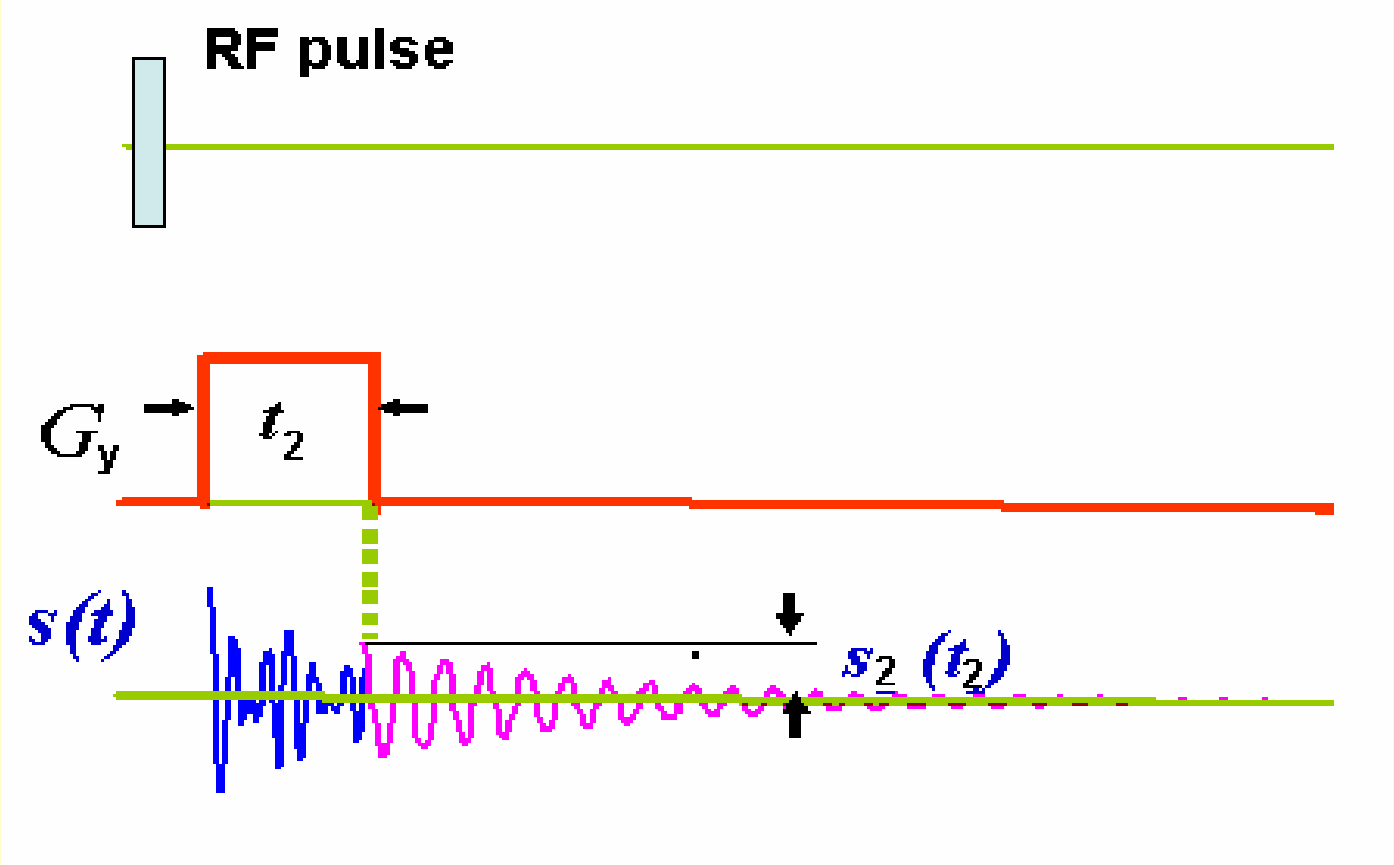


- ***On a frequency scale every frequency corresponds to certain coordinate.***

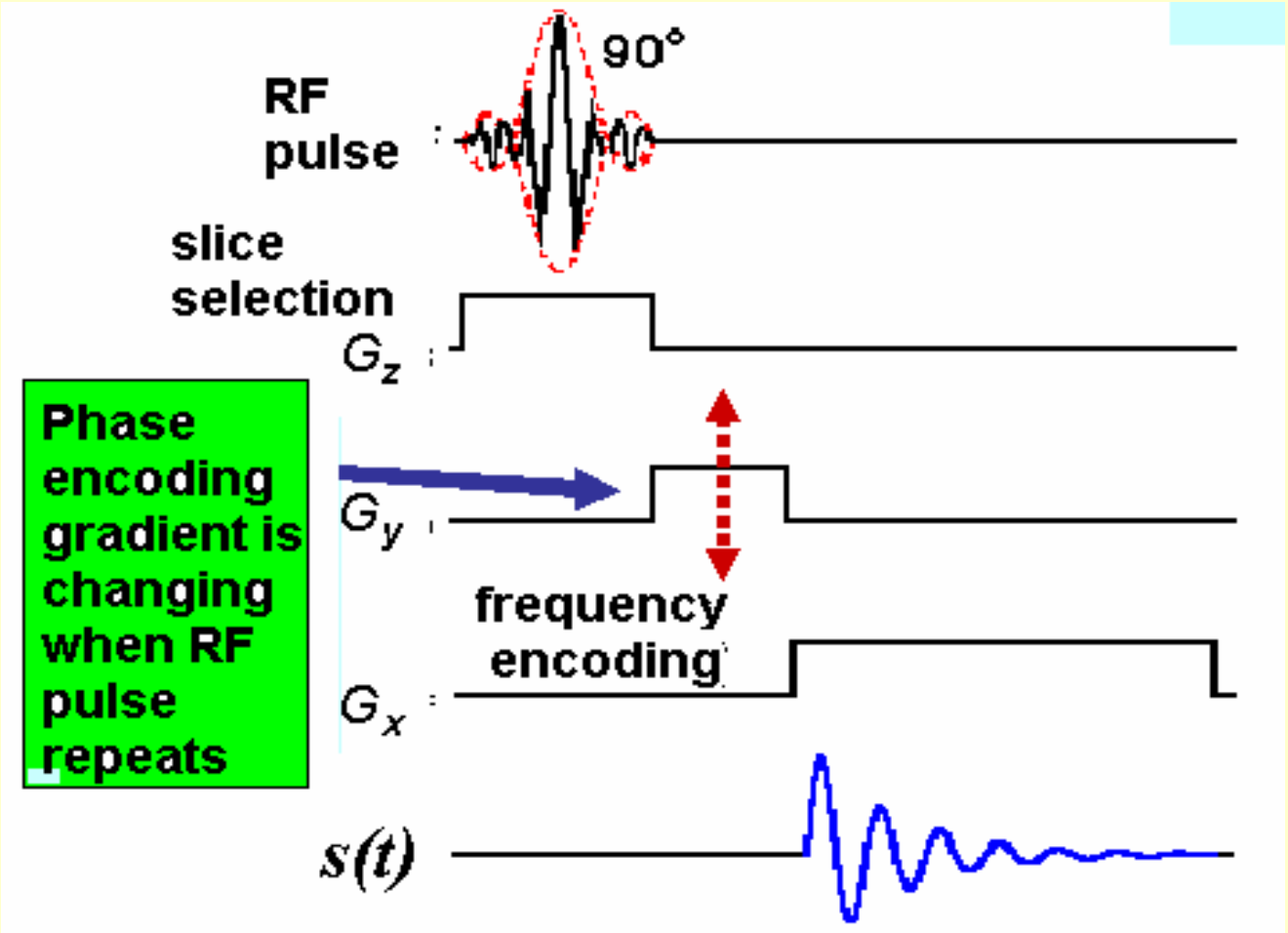
Pulse sequence for phase encoding

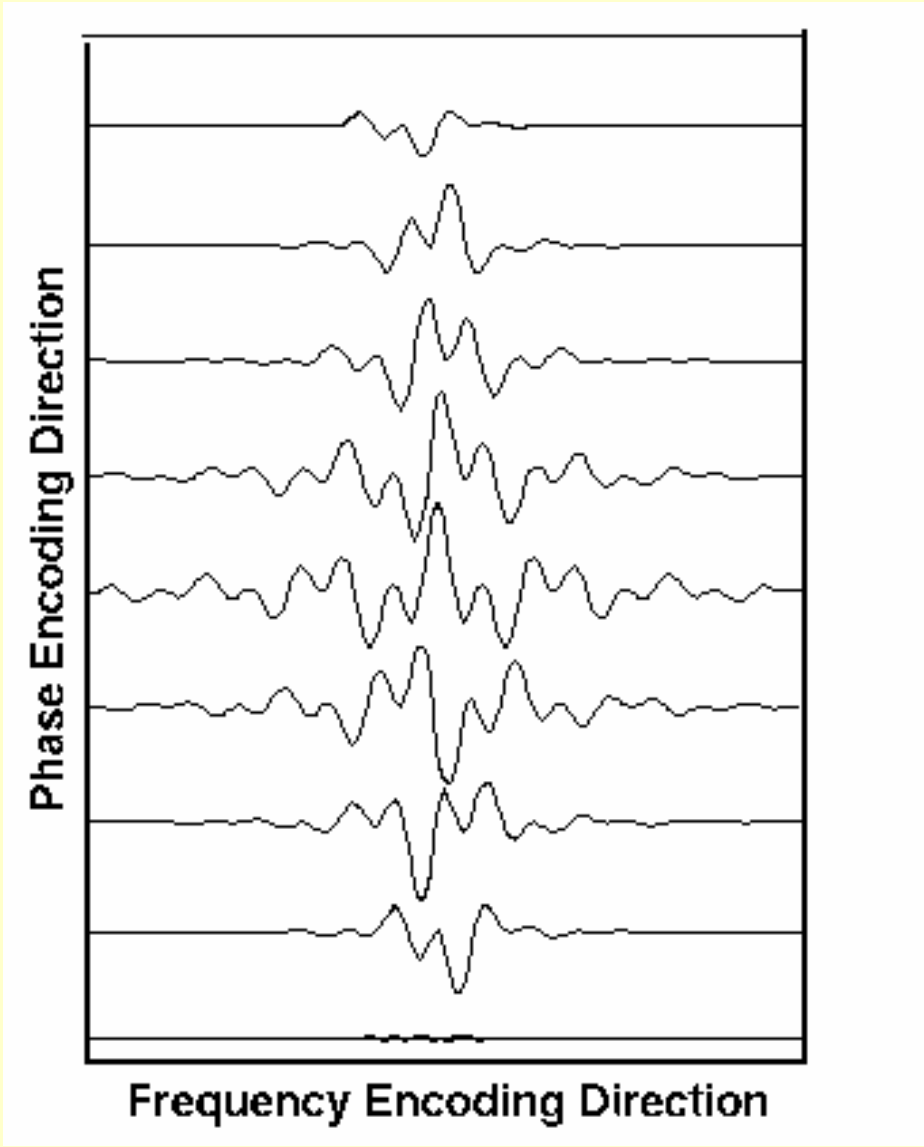


Pulse sequence for phase encoding



Sequence for slice image receiving



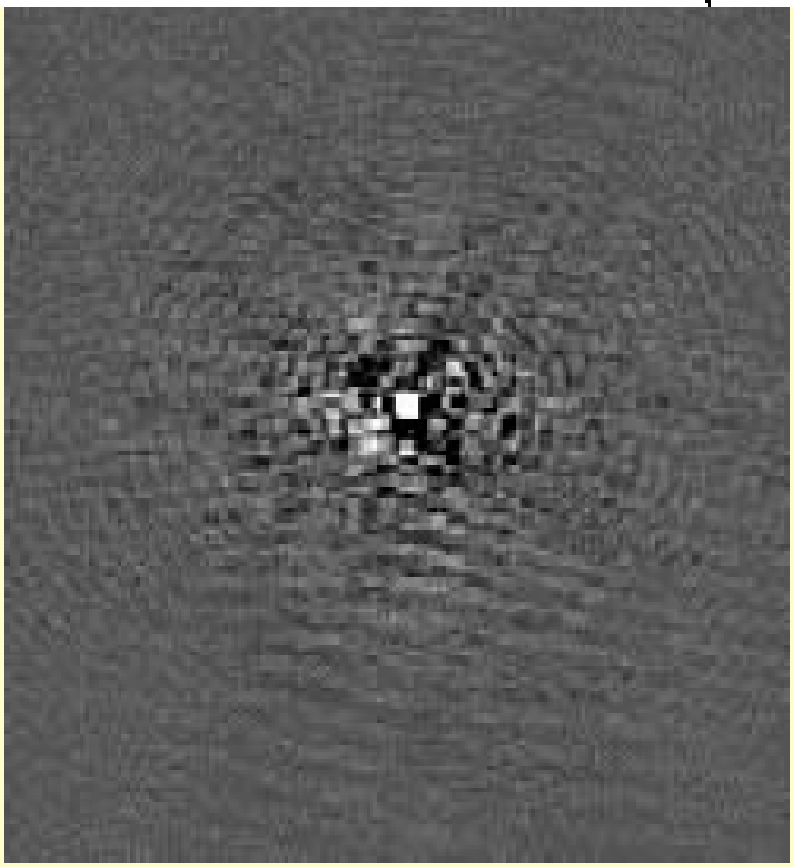


- Time diagrams of NMR signals (abscises axis) was received in acting different values Phase-encoding gradient

k-space

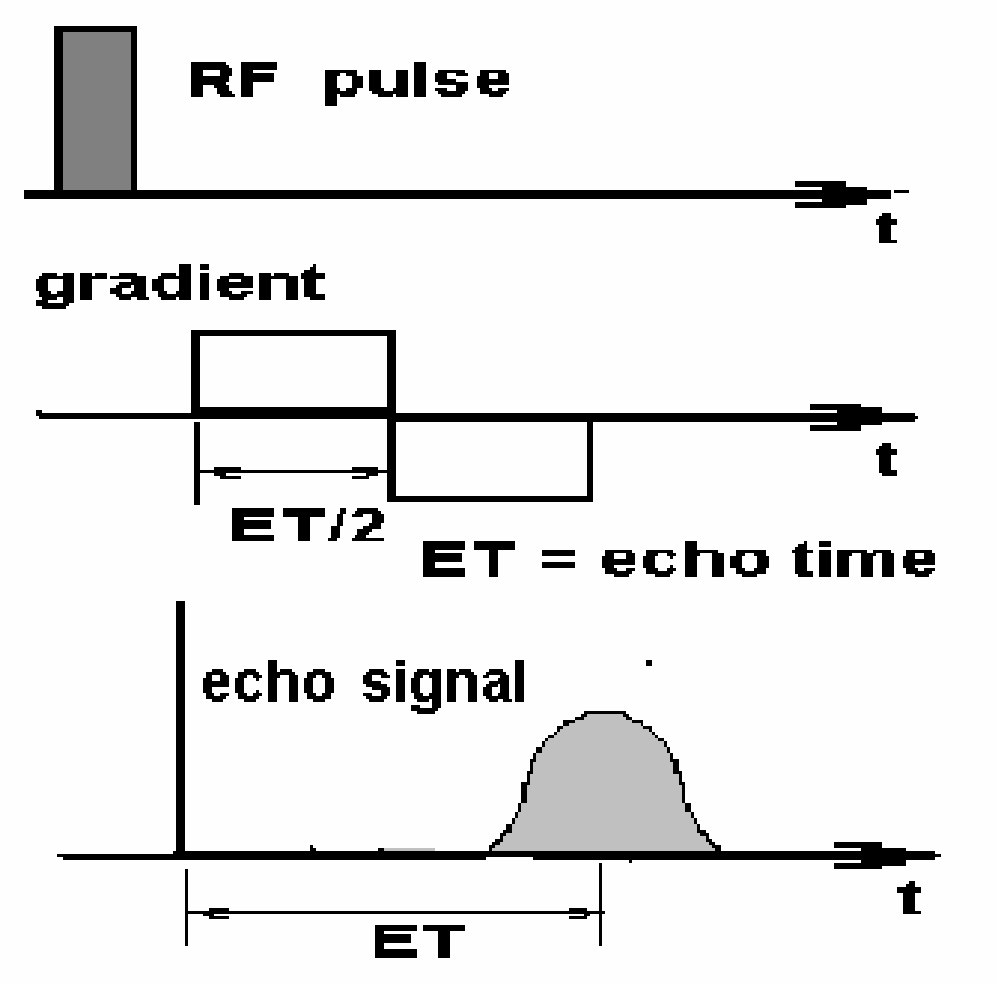
FT

r-space



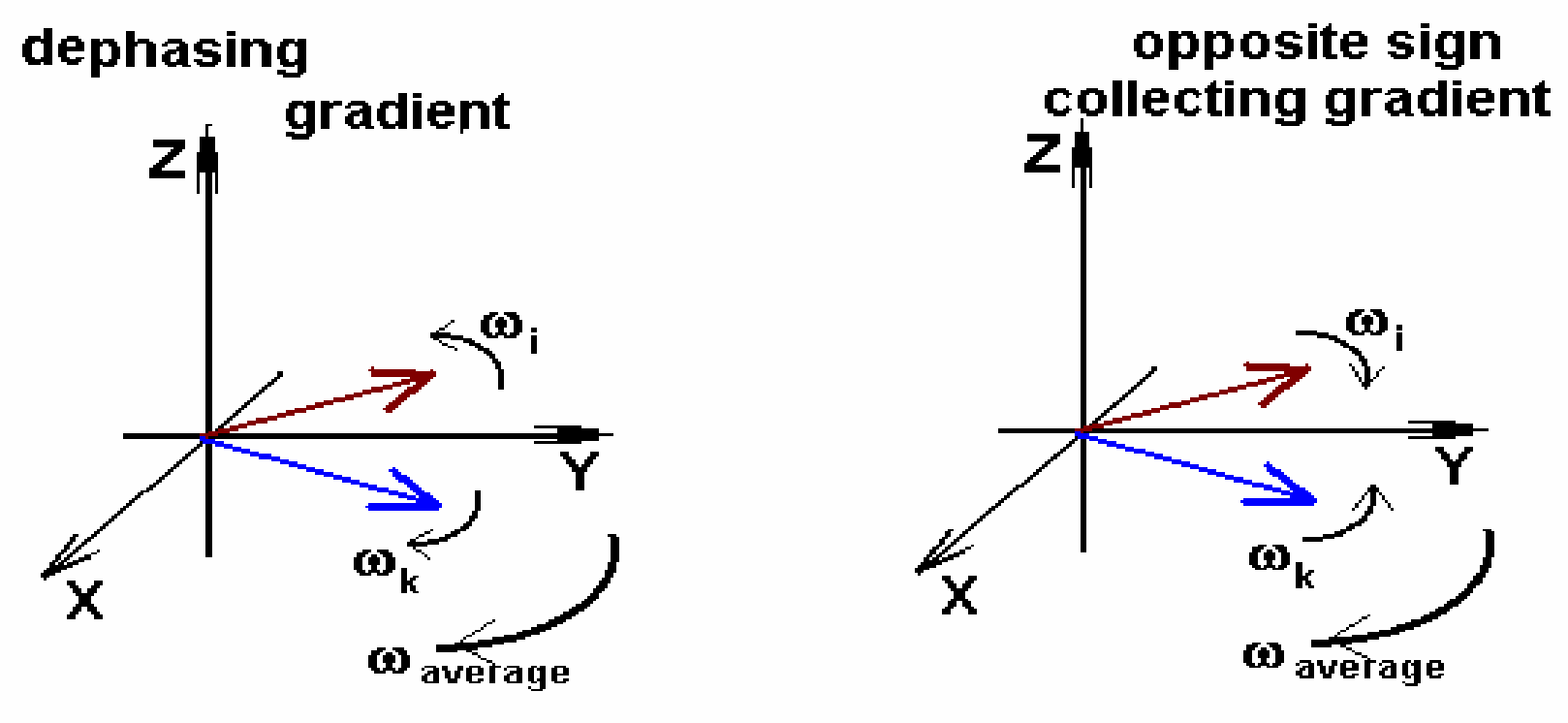
Echo signal

Gradient echo sequence



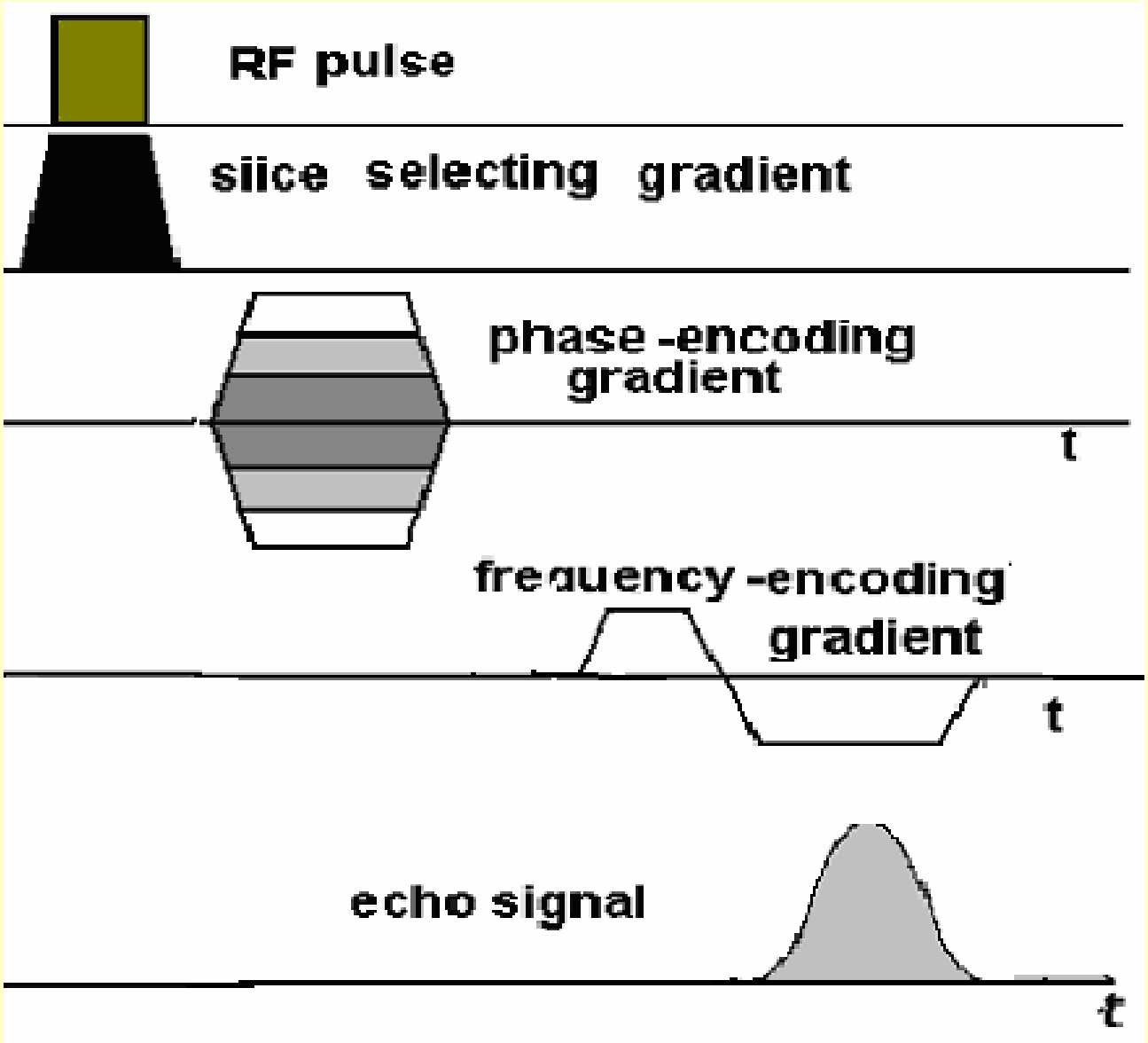
- TE time to wait to measure refocused transversal magnetizations

Mechanism of gradient echo

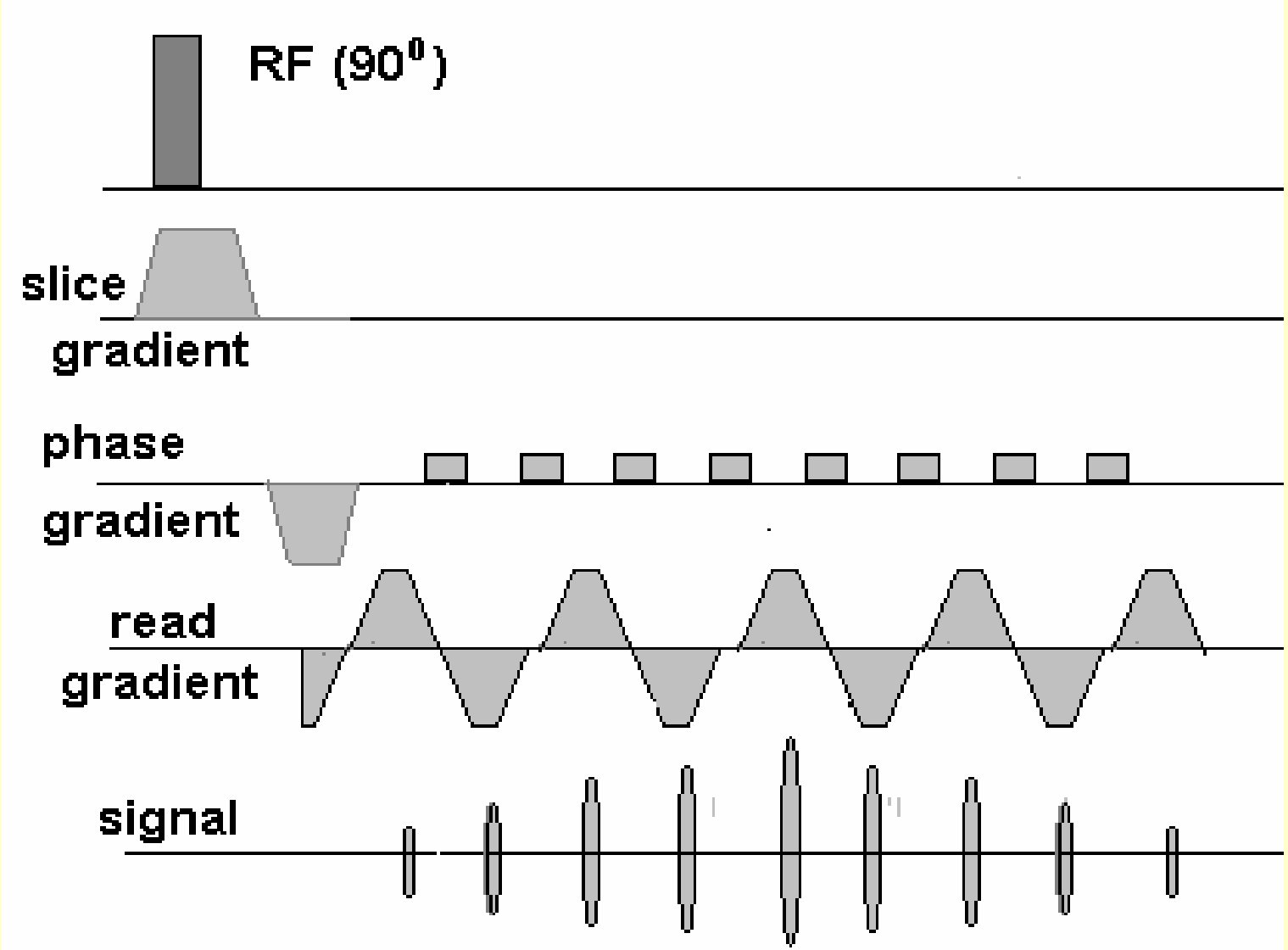


- After positive gradient has dephased transversal magnetizations, negative gradient collected them back

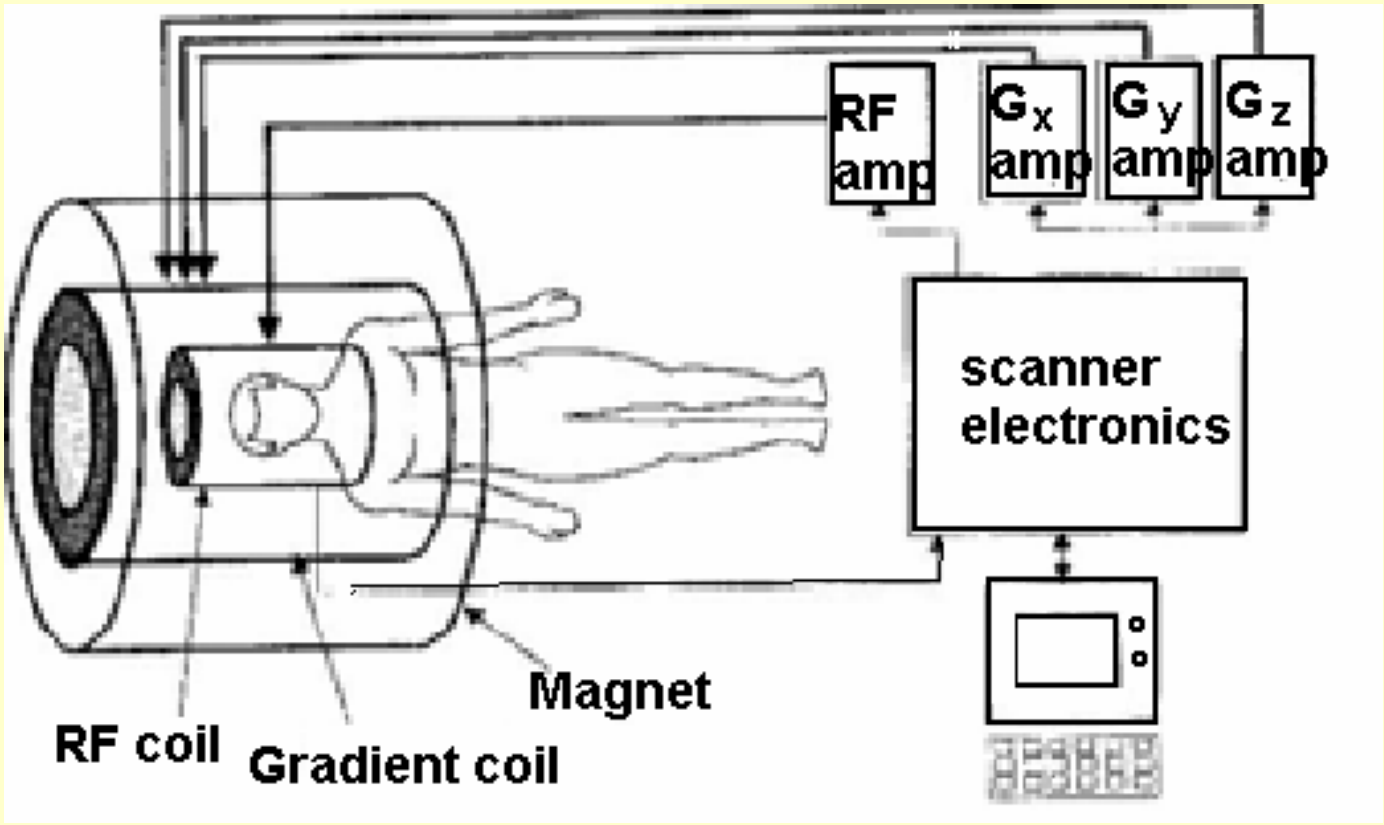
Echoes pulse sequence



Echo planar imaging scheme

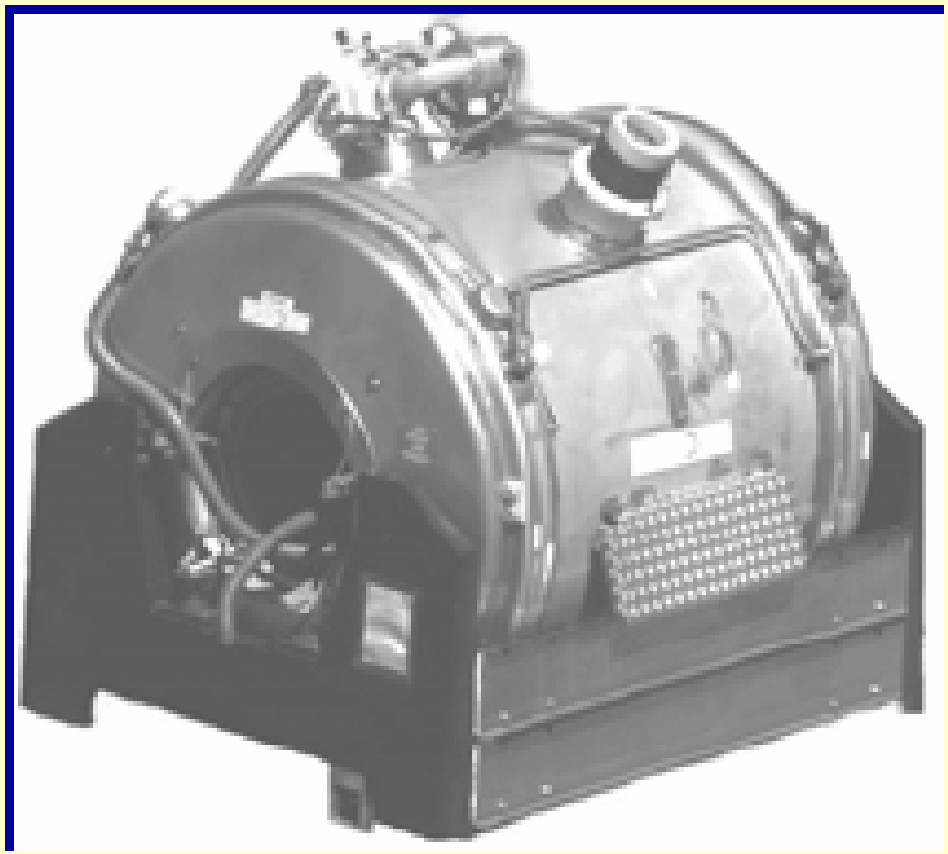


Necessary equipment



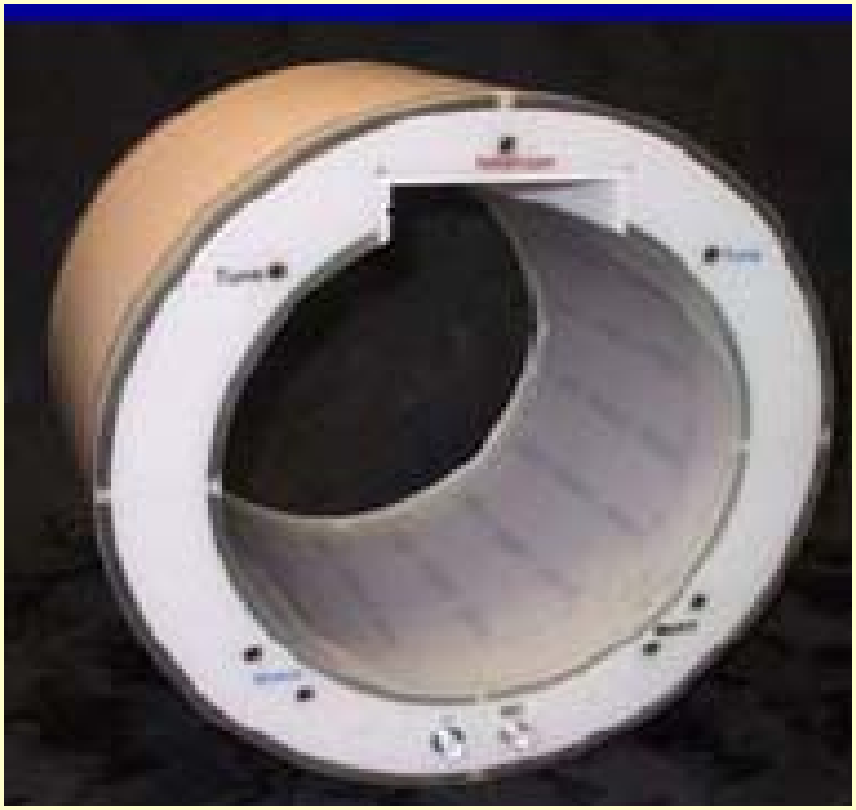
- The strength of magnet are 1, 1.5 or 4T

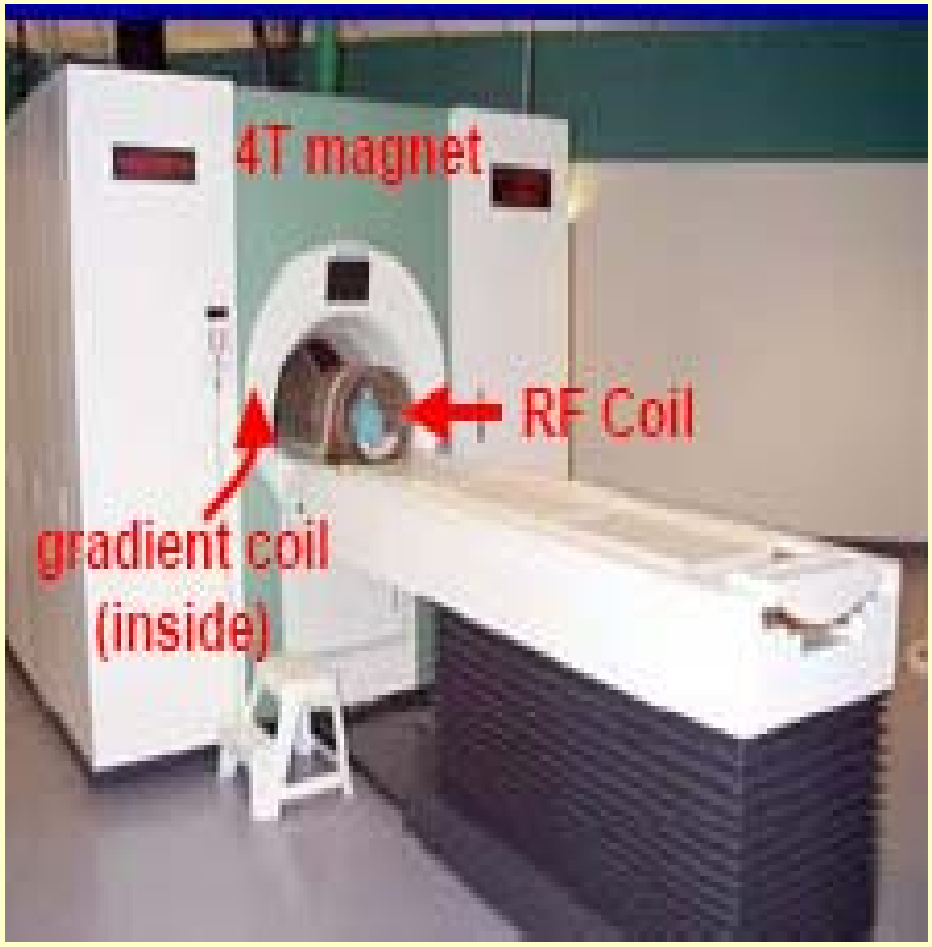
How it looks like



- Magnet

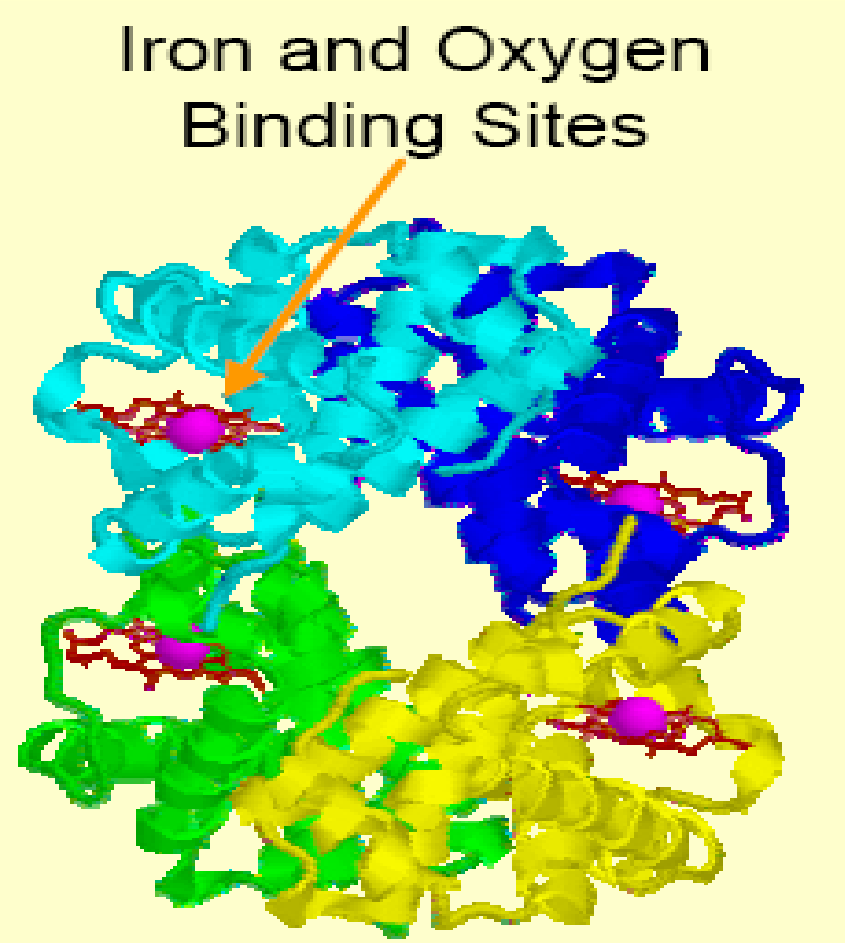
Gradient coil





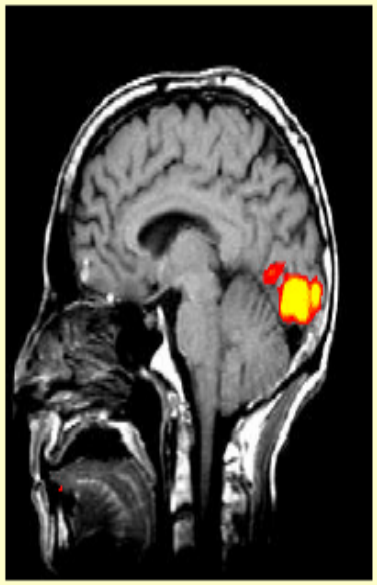
- RF coil

Blood Oxygenation Level Dependent signal (BOLD)



- **Oxygenated hemoglobin is diamagnetic**
- **Deoxy-hemoglobin is paramagnetic**
- **The presence of paramagnetic speeds up dephasing and reduces T_2^***

Connection brain function and MR signal



Brain function

↑ Metabolism

↑ CBV

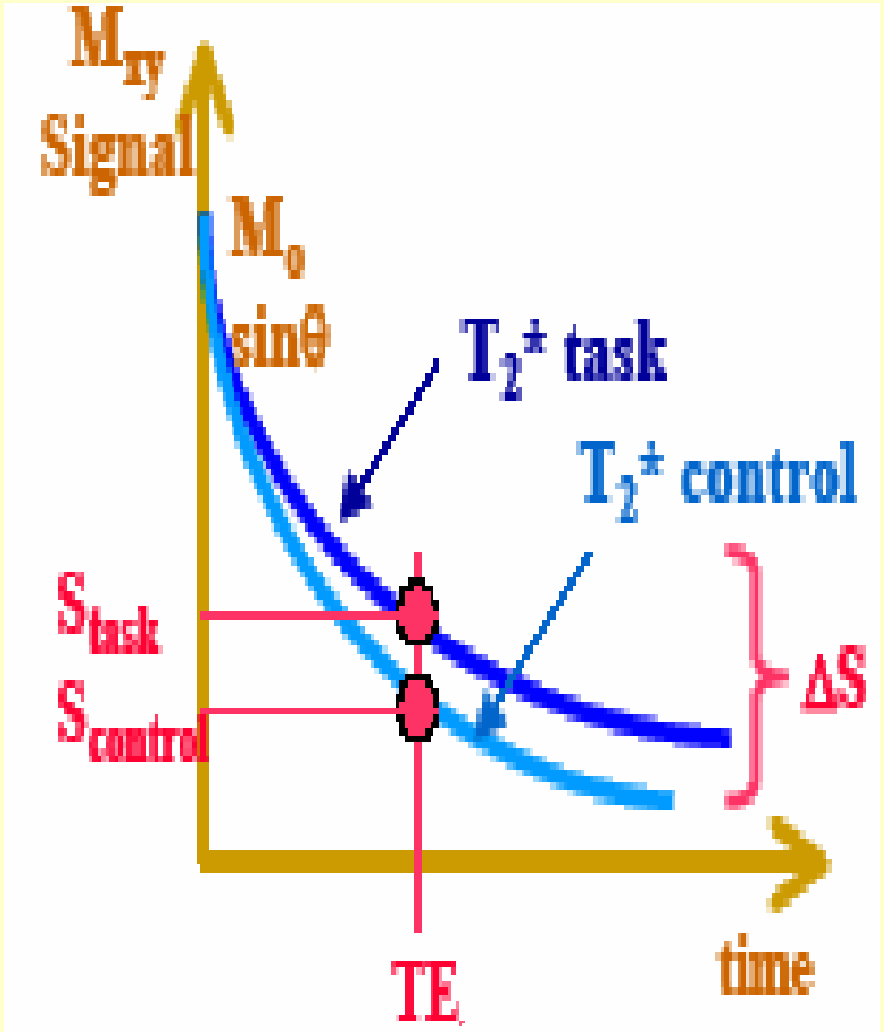
↑ CBF >> ↑ $CMRO_2$

↑ HBO_2 / HBR

↑ MR signal

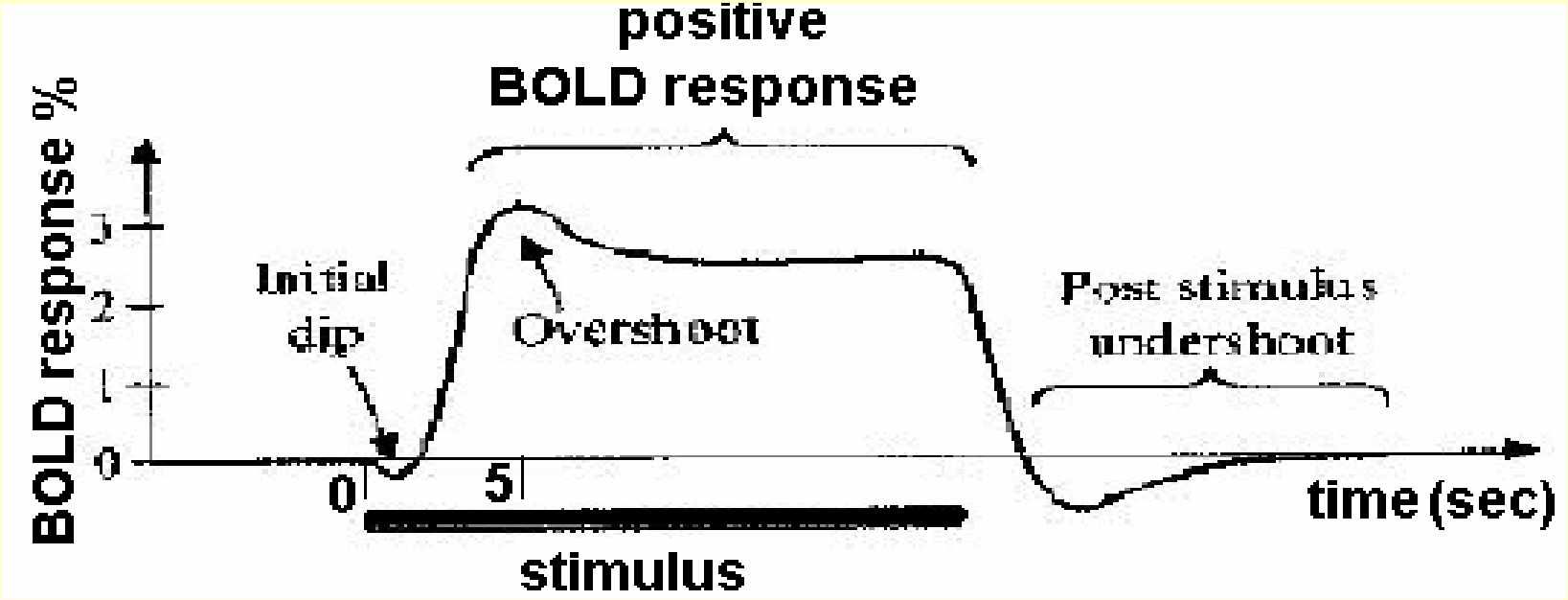
- Ratio diamagnetic to paramagnetic is higher, result are T_2^* longer and at right TE signal increase

Comparing T_2^* during task and control



- In presence of paramagnetic T_2^* is less. That leads to amplitude decrease and it is a control signal

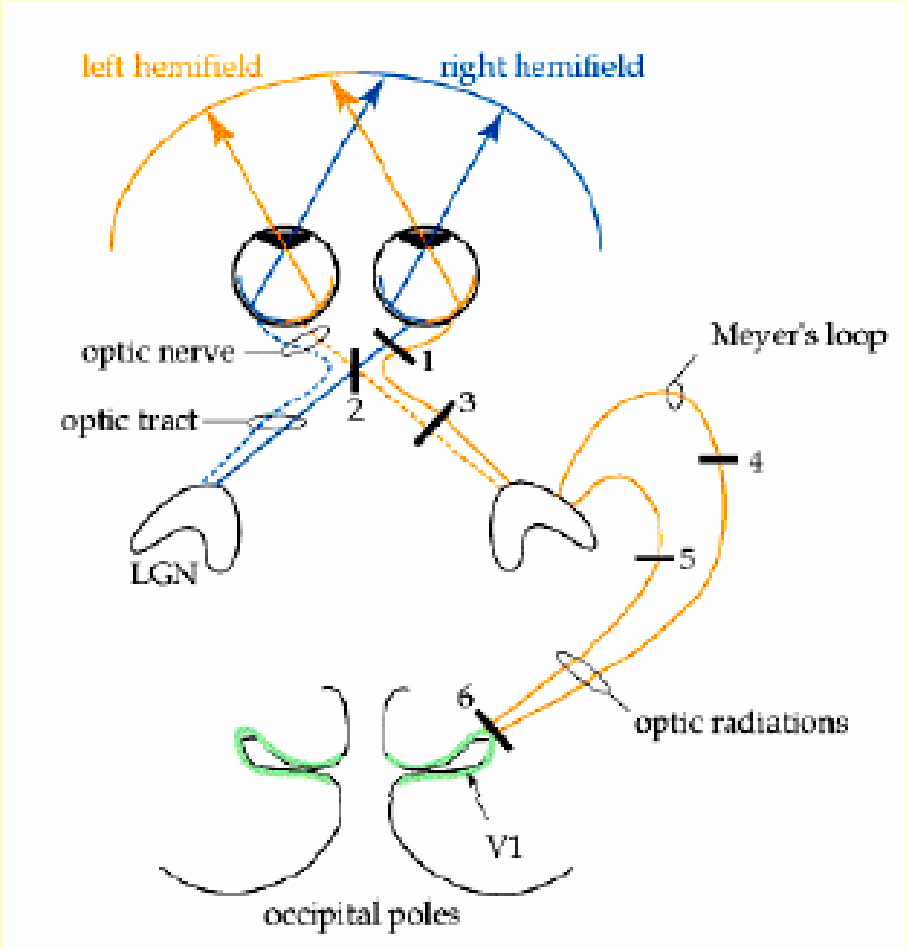
Hemodynamic response function

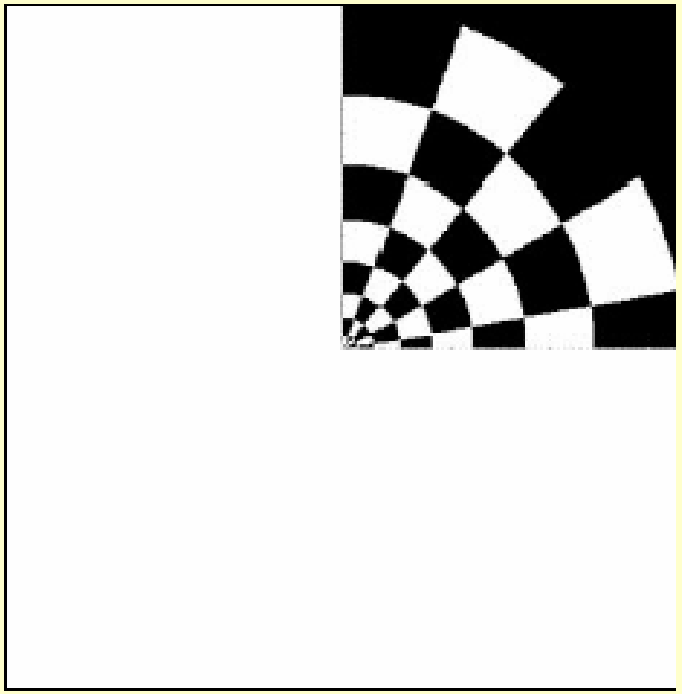


% signal change is 2-6 time to rise signal begins to rise soon after stimulus begins initial tip is could be too small, not everyone can find it time to peak is 4-6s after s.b post stimulus undershoot signals suppressed after stimulus ends

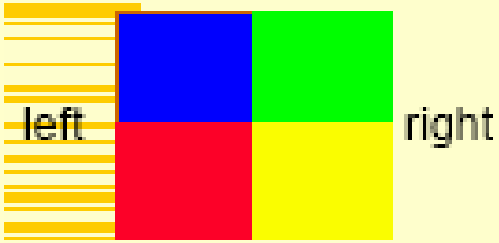
Some examples of applying fMRI

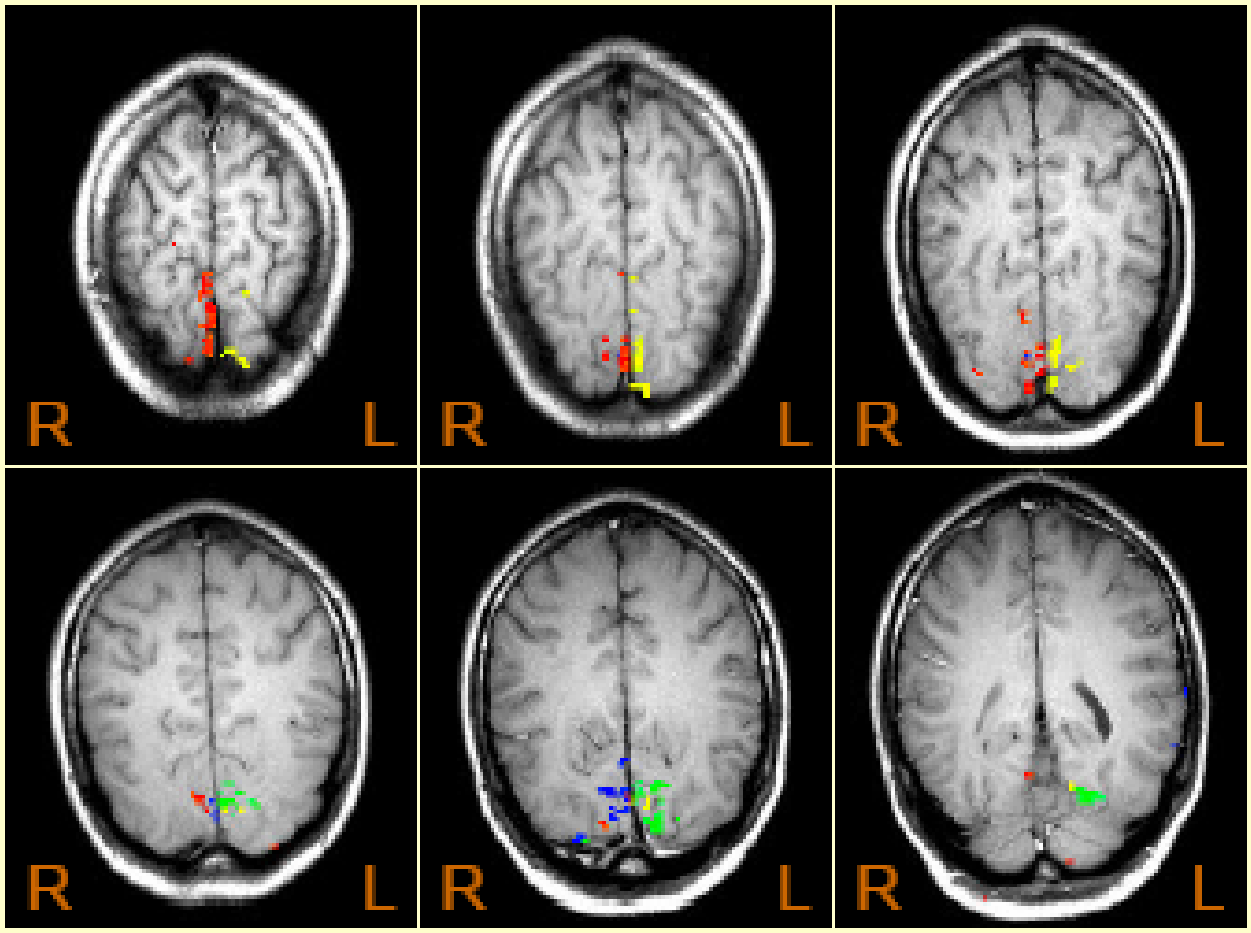
Visual Field & Retinotopy: Quadrant Stimulation





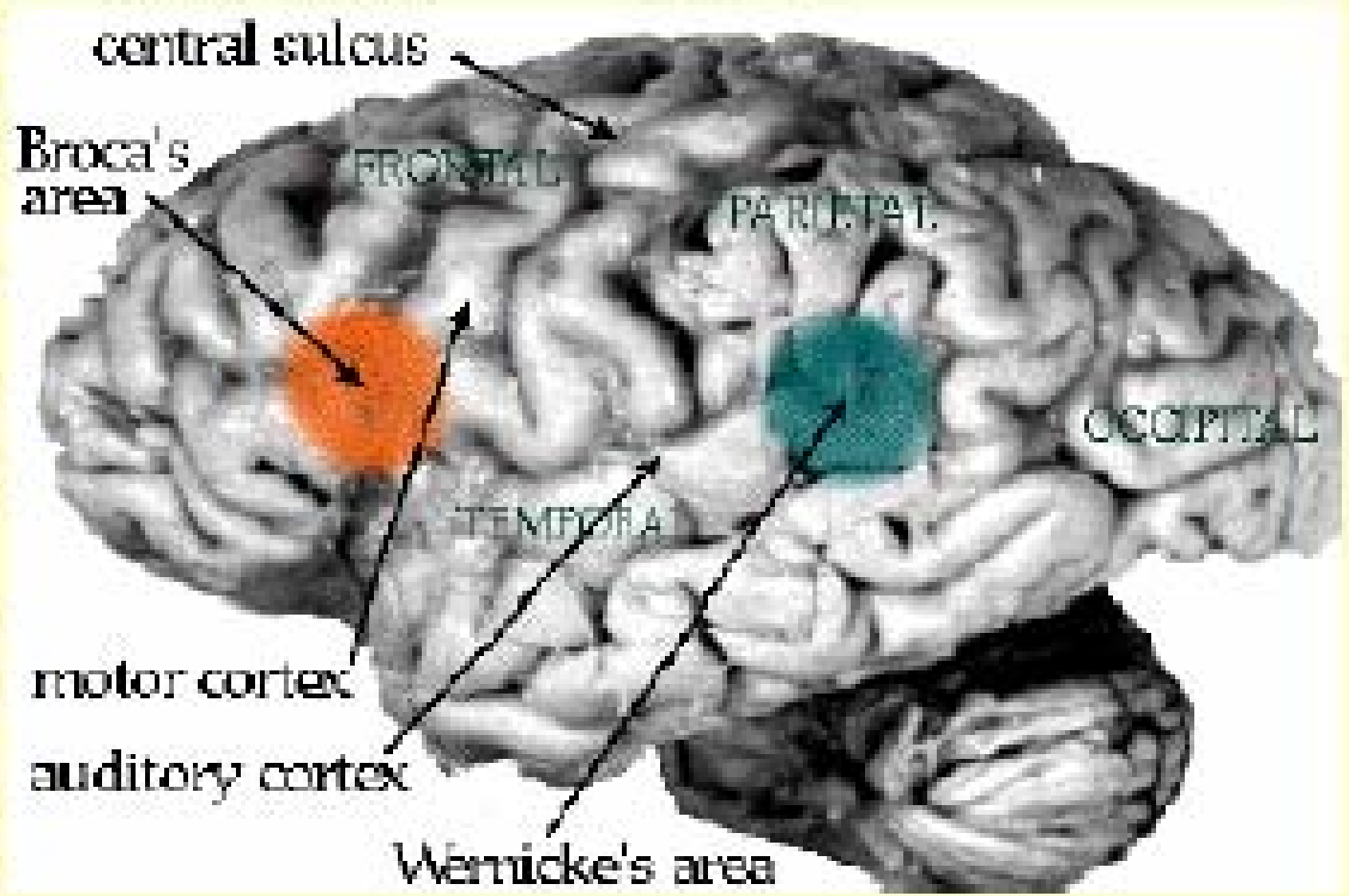
Quadrant Stimulation





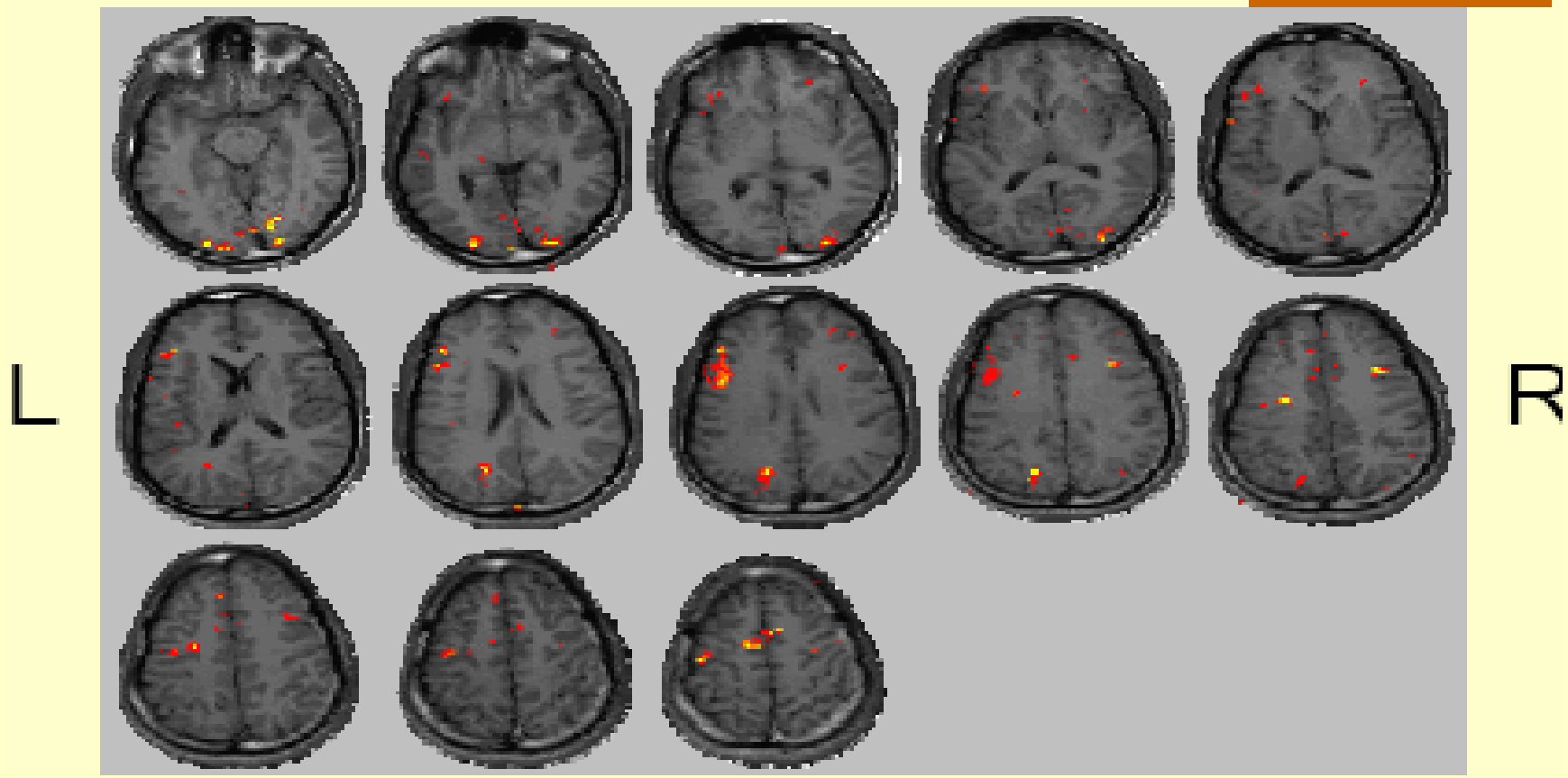
www.kispi.unizh.ch/Magnetresonanz/pdf/fMRI.pdf

Mapping the Language Area



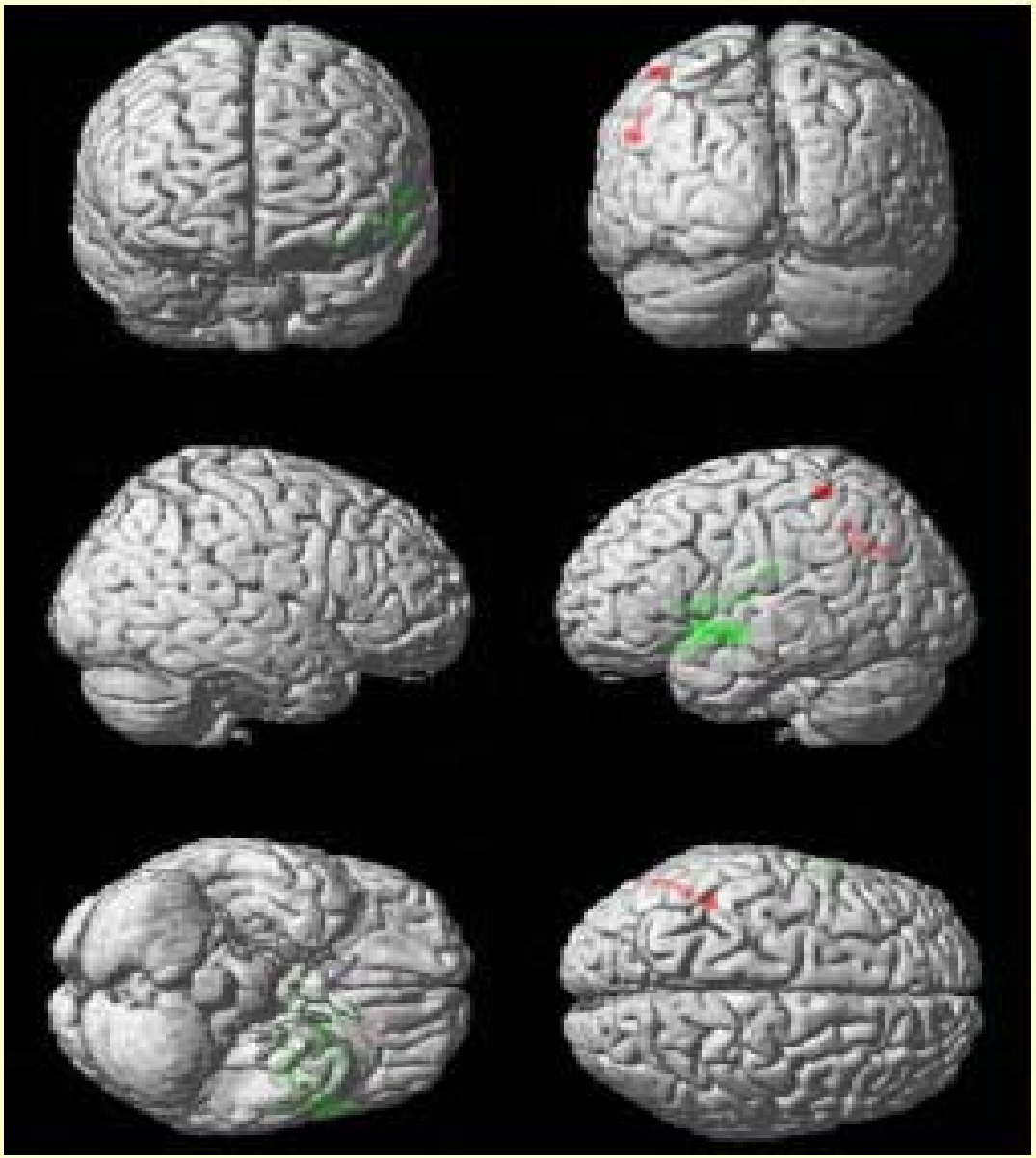
Subject Reading Swiss Words

Vitacco, Brandeis, Pascual-Marqui et al, 1998



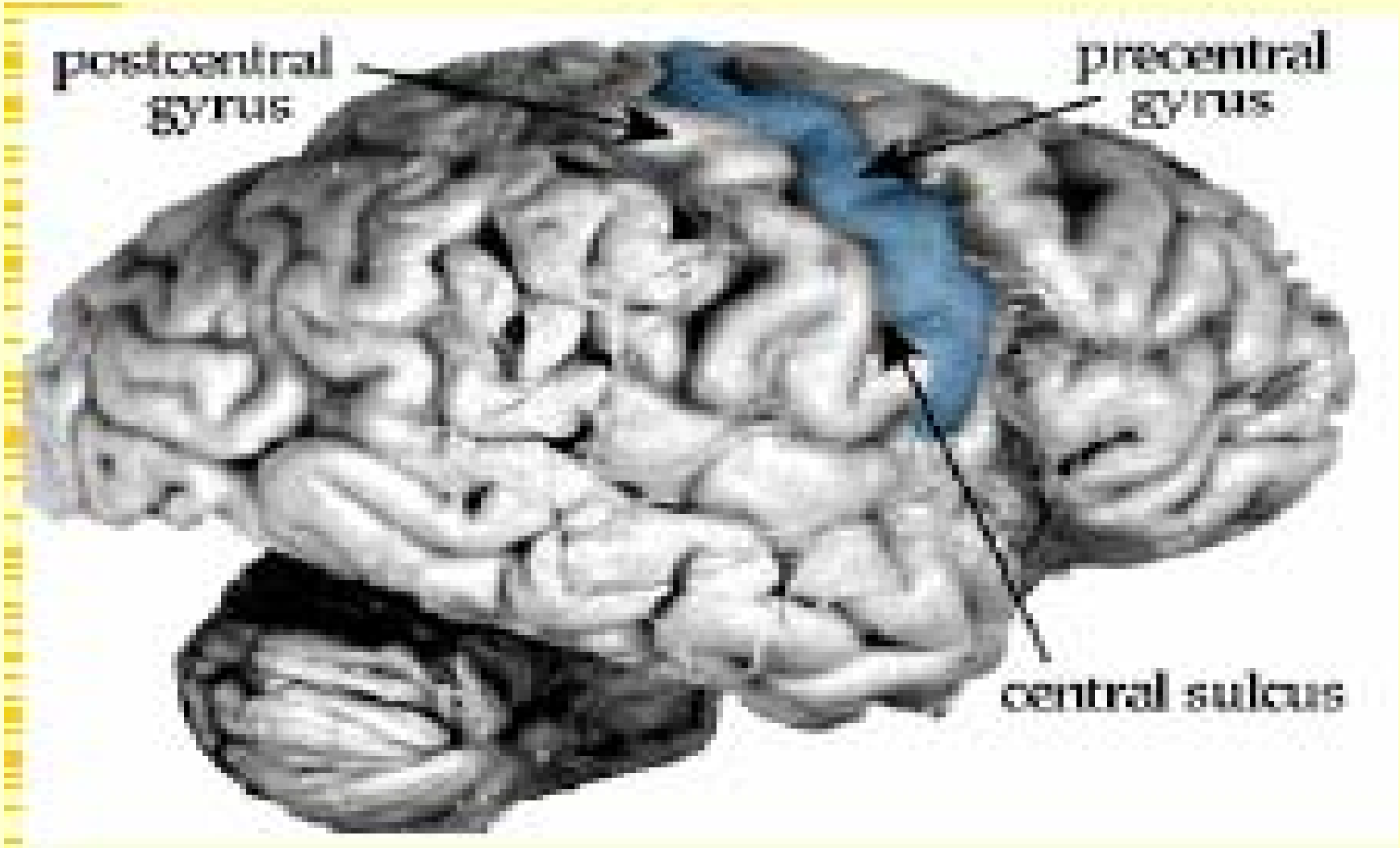
Active zones of whole brain slice by slice. Subject adult and healthy

Calculation in adults and children



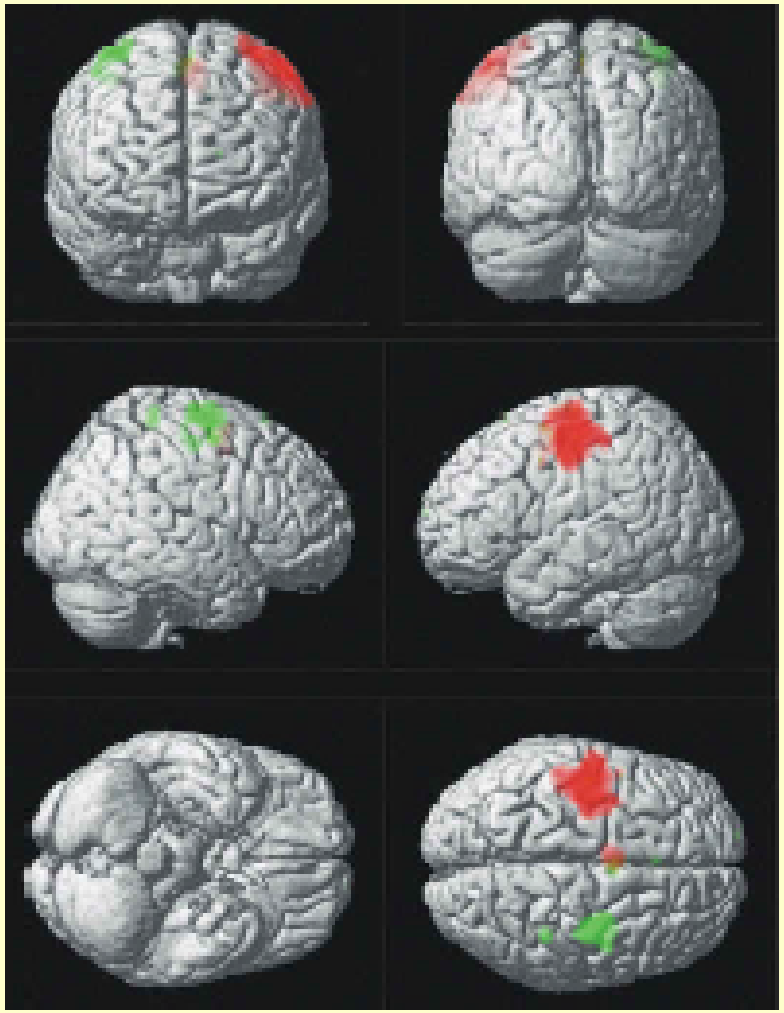
- Red label is adults
- Green label is a normal achieving school children
- Frontal, Sagittal and Axial views

Mapping the Motor Areas



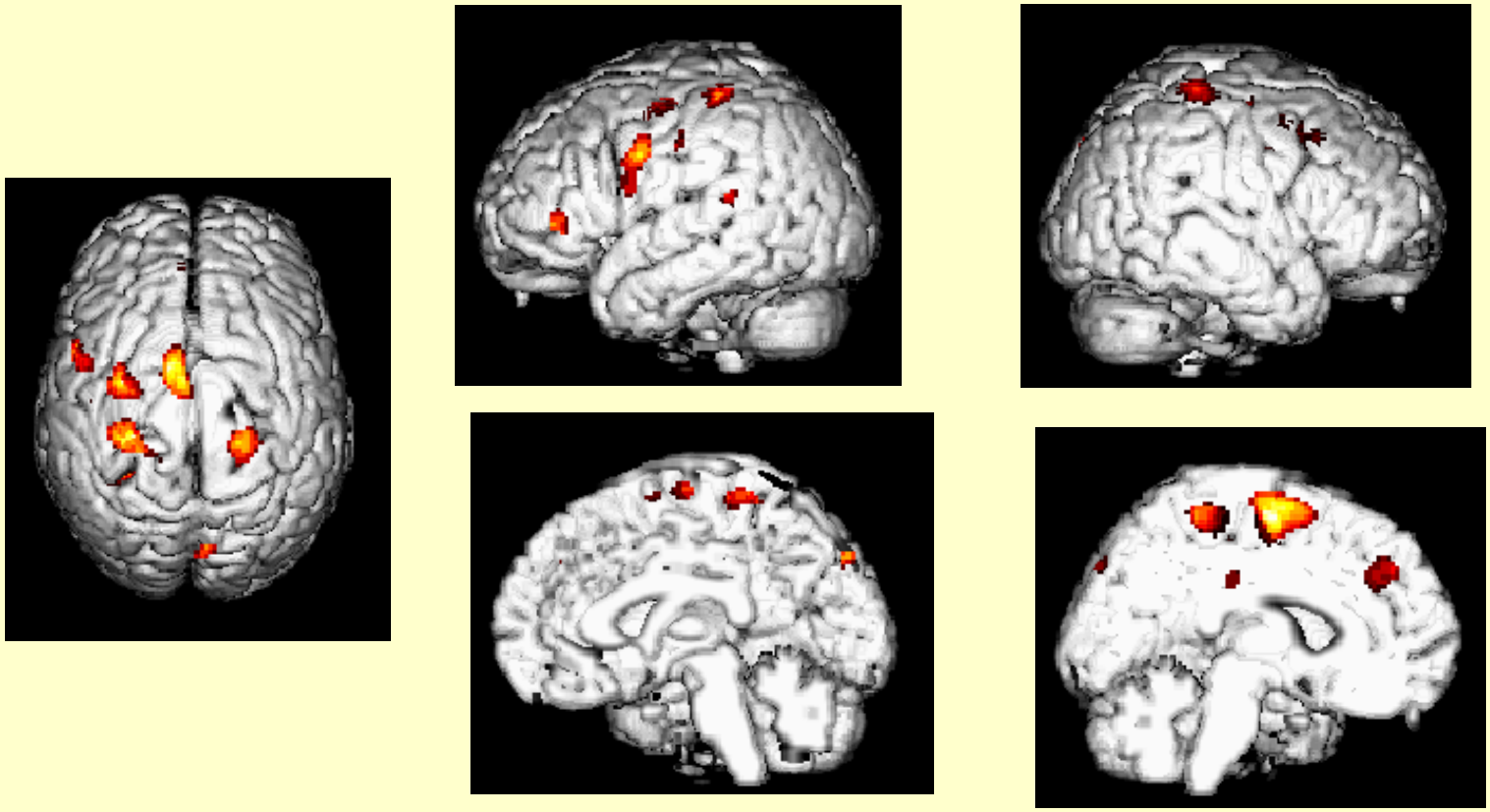
Sequential Finger Tapping

Marcar, Loenneker, Martin, et al, 2001

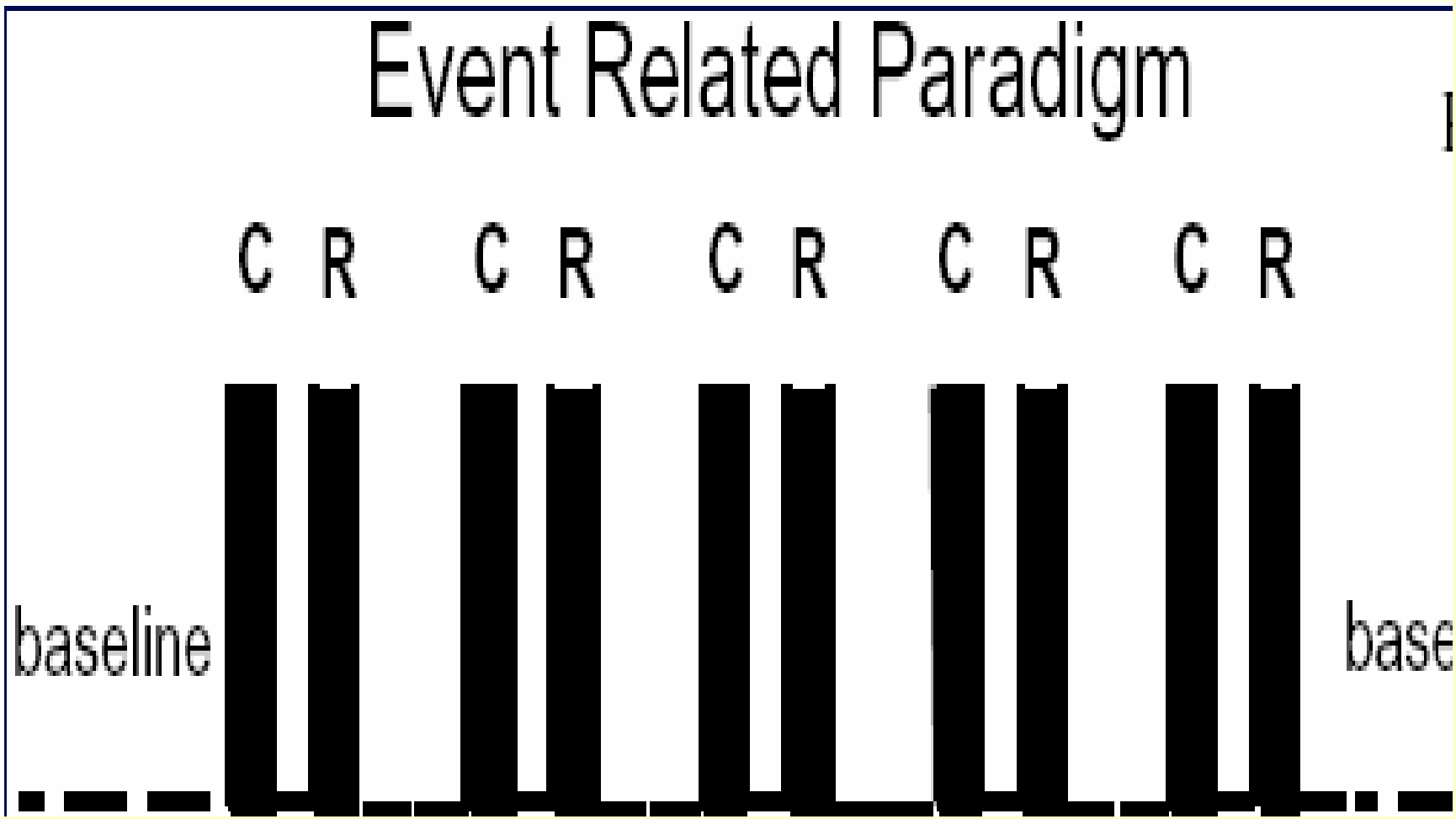


- Sequential **left hand** and **right hand** finger tapping task in an eight year old child

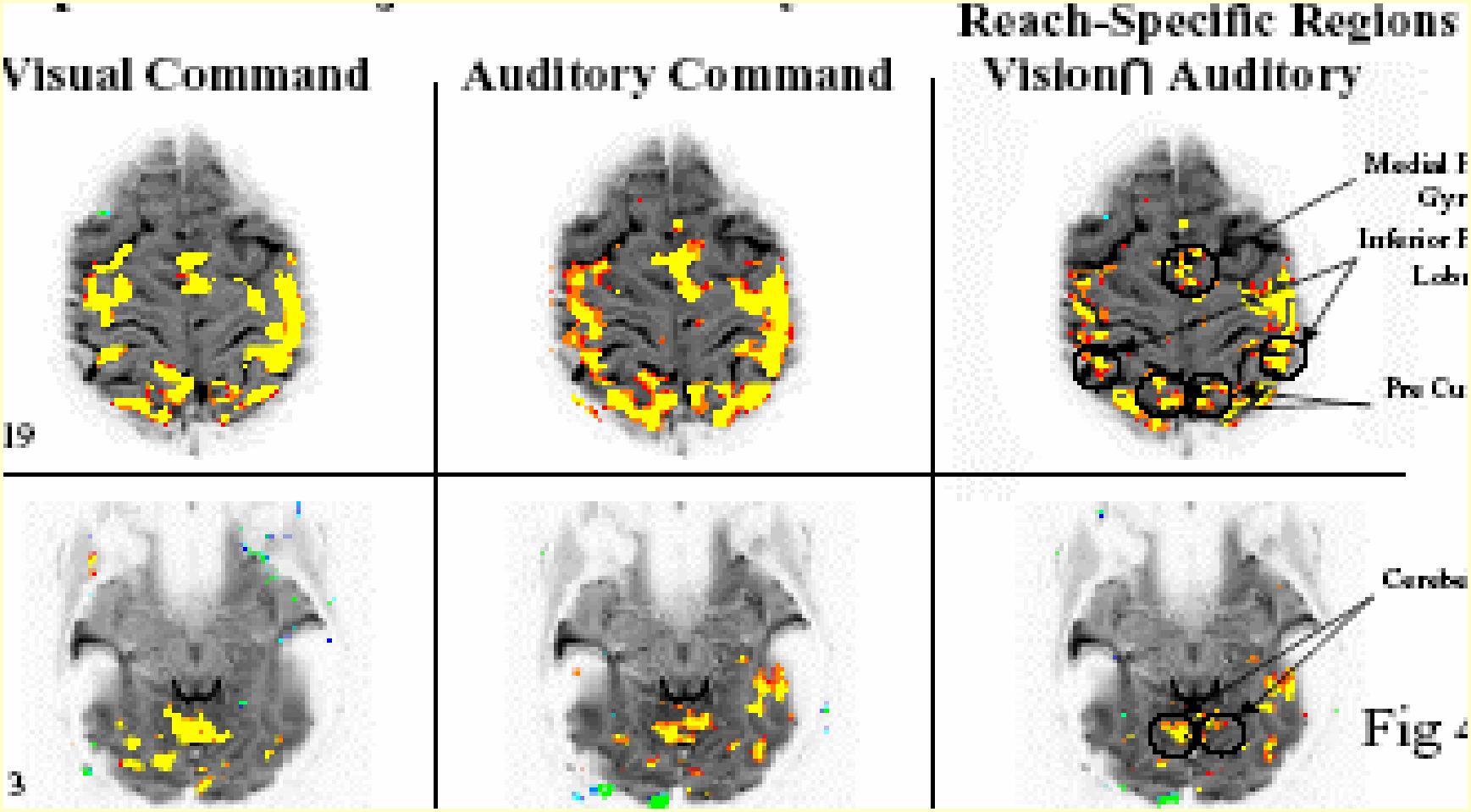
Data receiving by PET (O-15)



- Images a motor areas of scratching

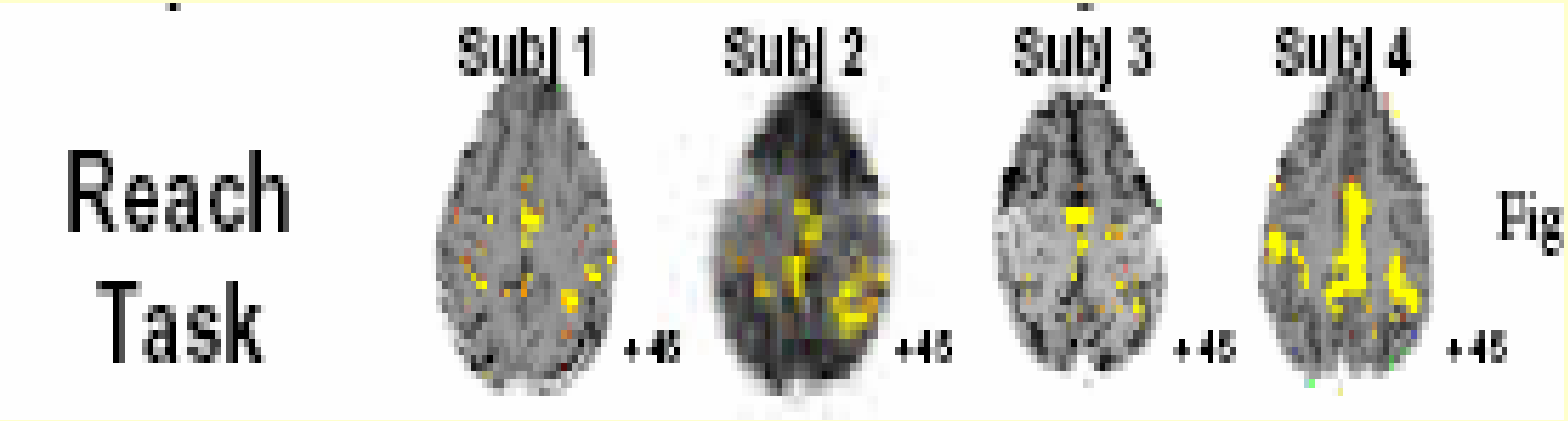


- C-command R-reach



Medial frontal gyrus, inferior parietal lobule, lower is cerebellum

Averaging is necessary



- This slide illustrates the individual patterns of responses for 4 subjects on a comparable slice of brain.

Results – Mapping of sagittal slice

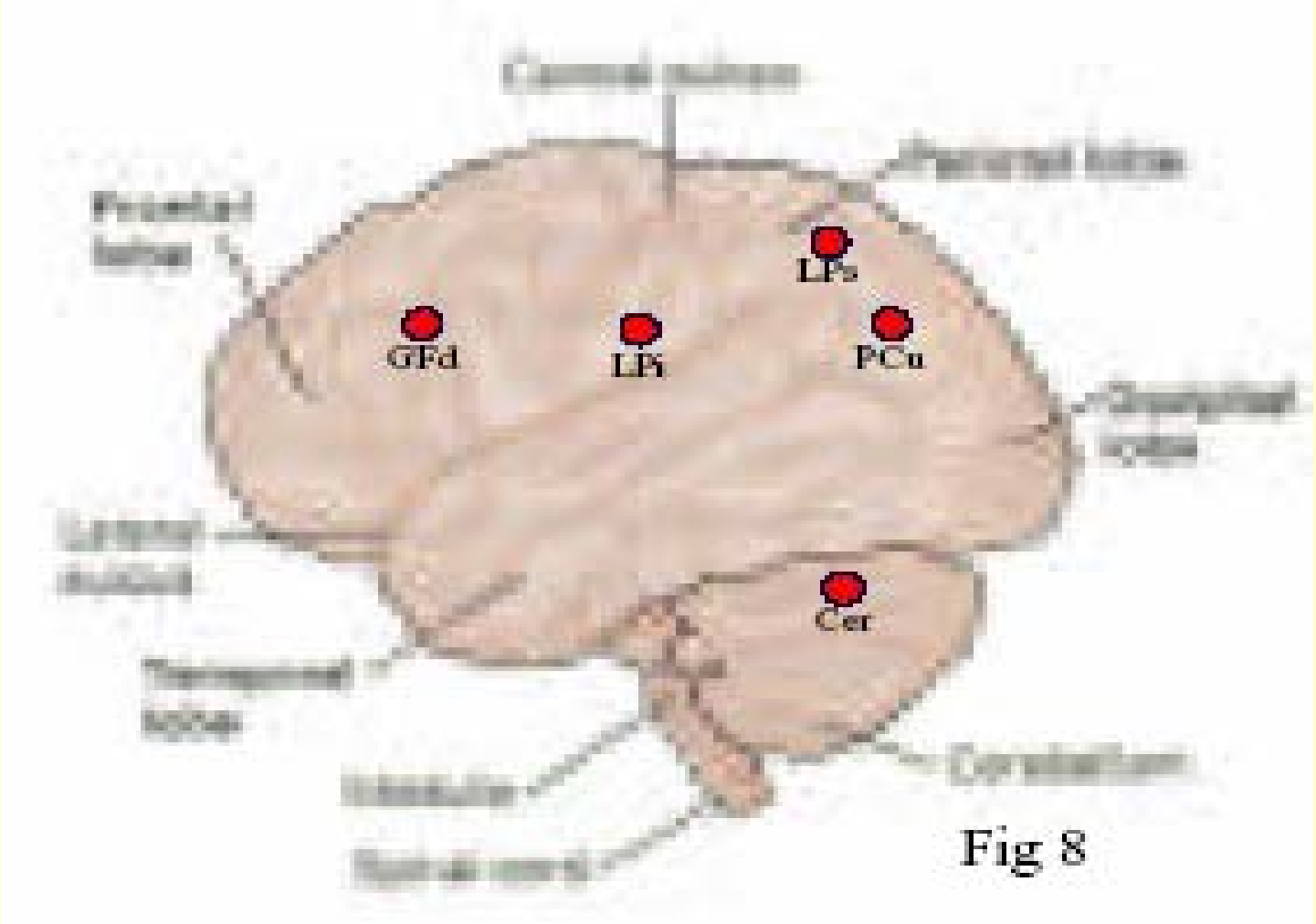
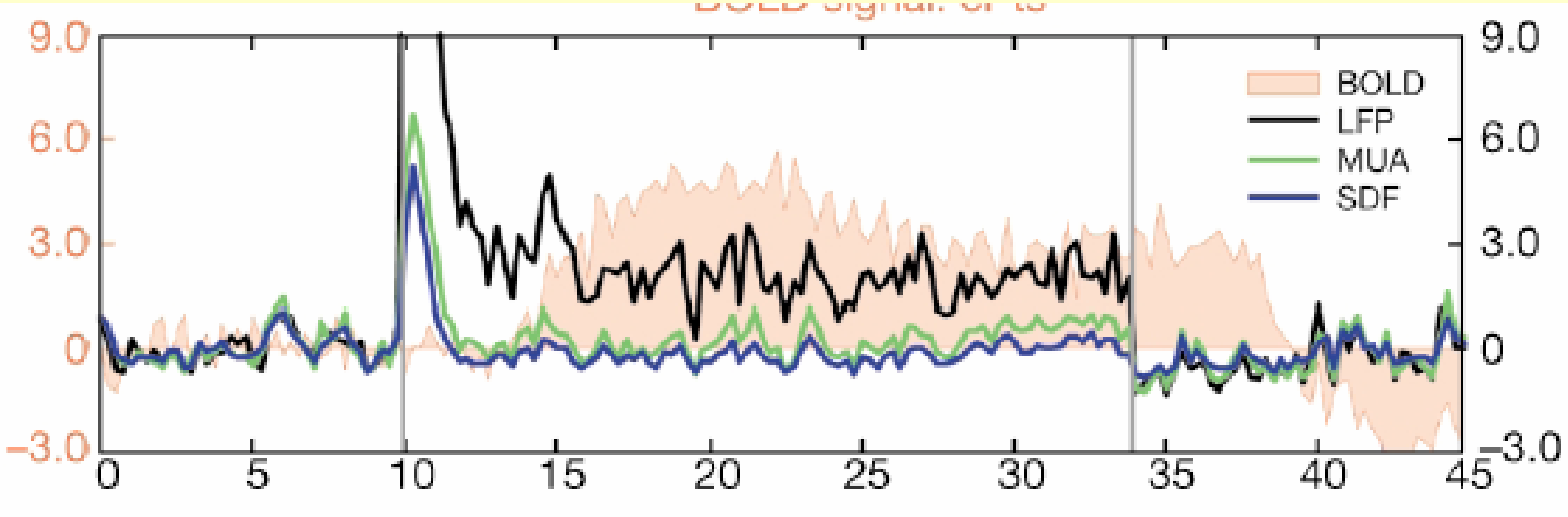


Fig 8

J. Hirsch [1,2], R. Silver [1], S. Kleiner [1], L. Rothman [2], D.T. Barry [3], Weill Medical College of Cornell University, New York, Memorial Sloan-Kettering Cancer Center, New York, NY [2], Johnson Space Center, NASA, Houston, TX[3].

Correlation between BOLD and LFP



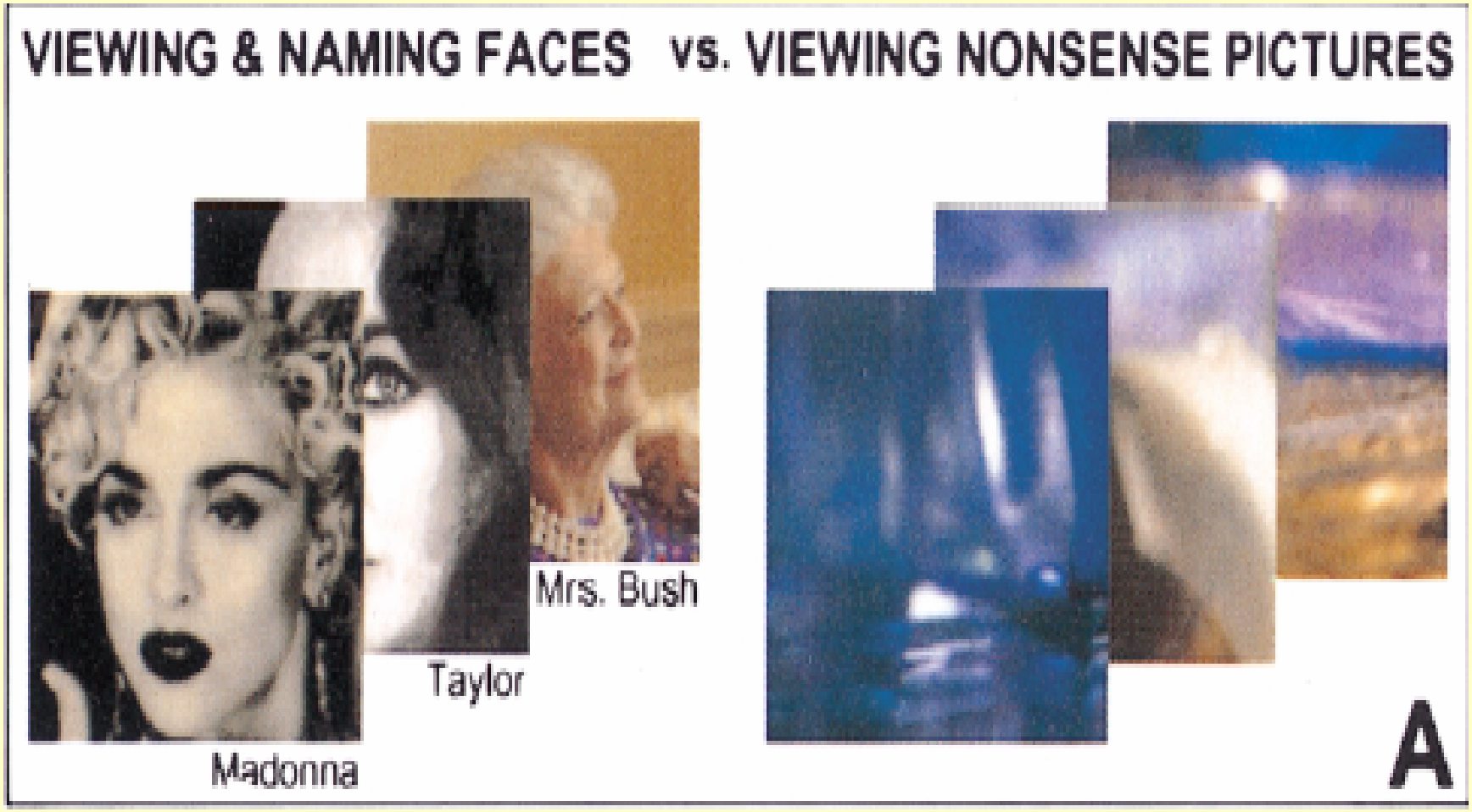
- LFP - local field potential

Recorded trough the a microelectrode while anesthetized monkey was visually stimulated. LFP reflects neuron activity. It a sum of the membrane potentials from neurons

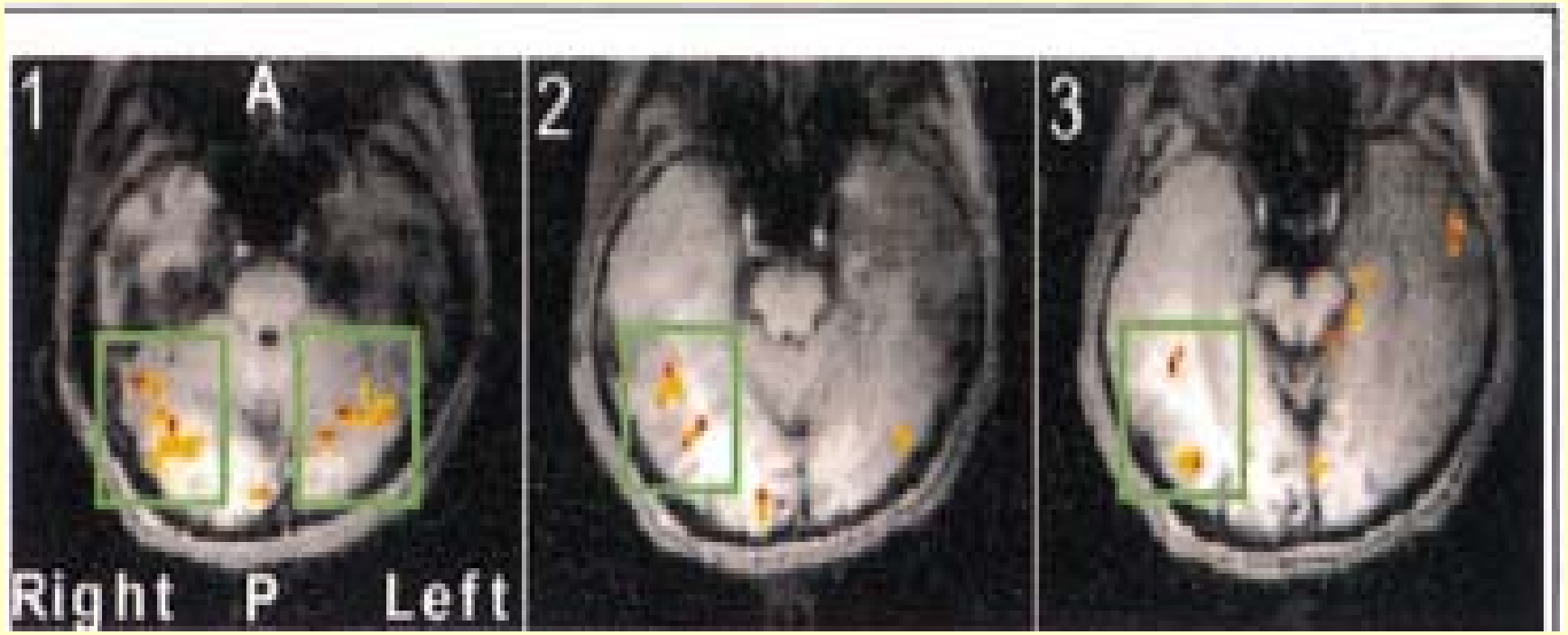
http://neurosci.nature.com

Advantages and disadvantages of high static magnetic fields

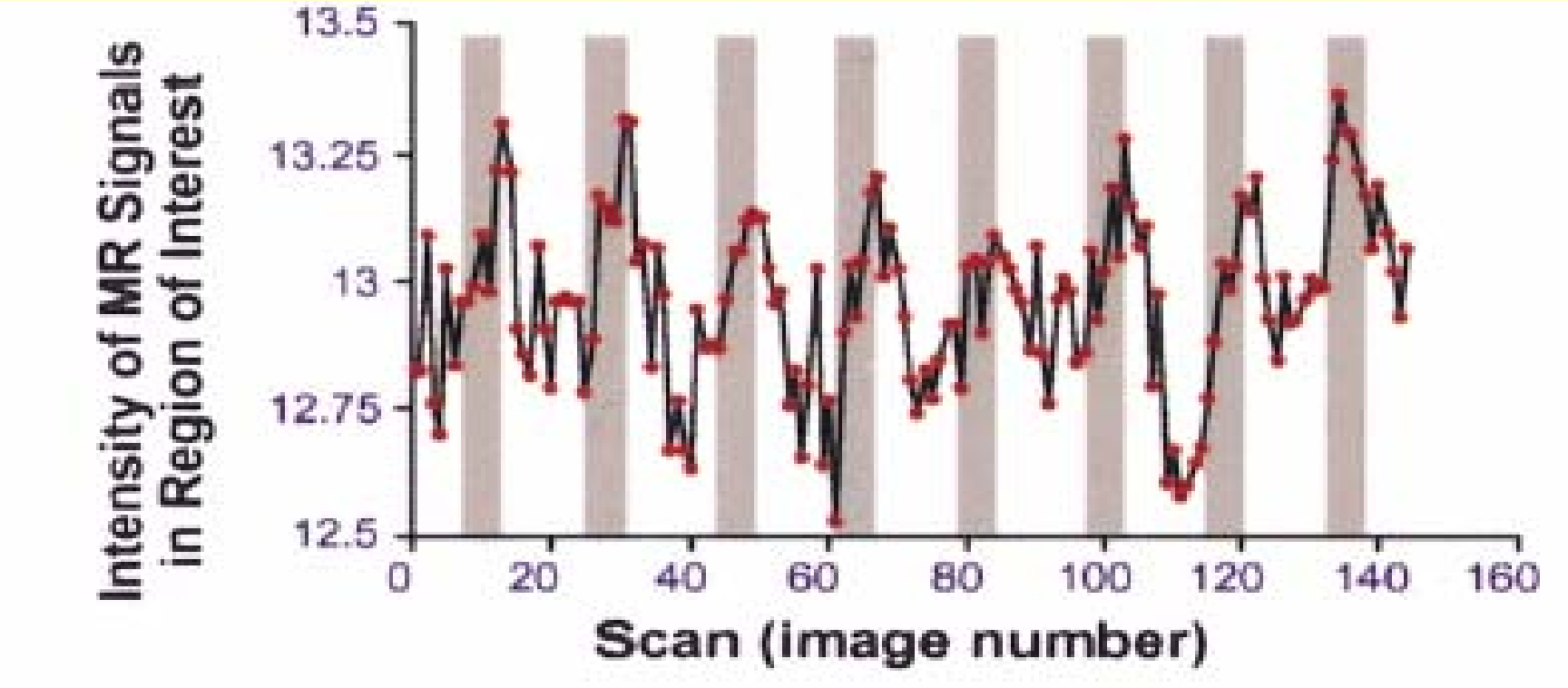
- **MR signals increase because the magnetization of sample is proportional to the field strength.**
- **The increase of MR signals improves the signal to noise ratio.**
- **The decay time of magnetization signal due to dephasing (T2*) is shorter**
- **The susceptibility artifacts due to the inhomogeneity of the statistic magnetic fields are lager**



Examples of the picture of familiar faces and nonsense pictures.



- There are activation patterns when a healthy volunteer recognized familiar faces.



- Data points obtained from scans in region of interest when face pictures are viewed are shown with gray background.

- Thank you very much for your attention

- Acknowledgements
- Pr V.V.Frolov
- Pr V.I. Chizhik