An introduction to Transcranial Magnetic Stimulation (TMS) and It's Application

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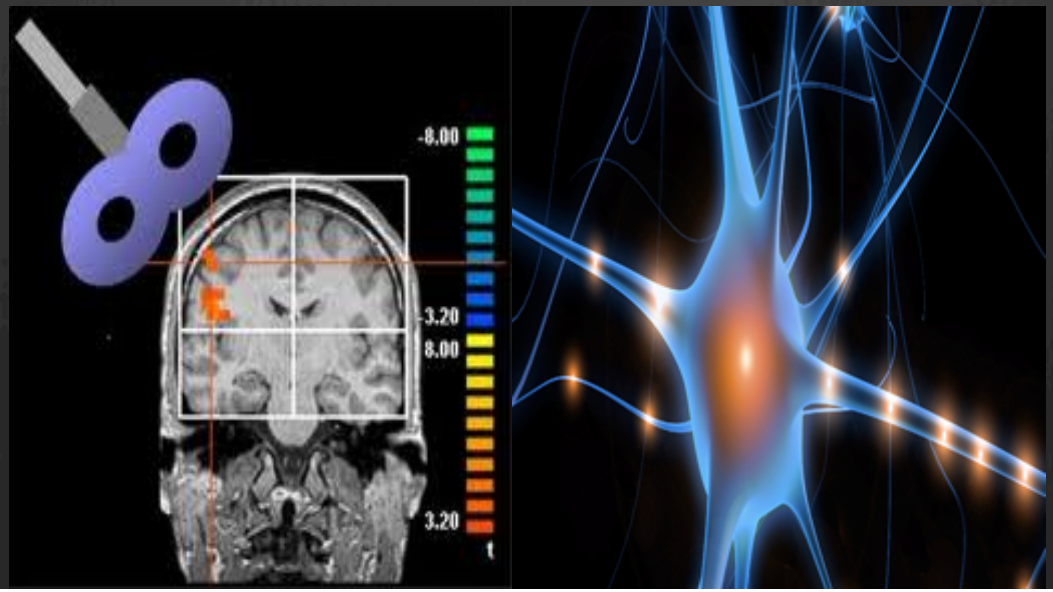
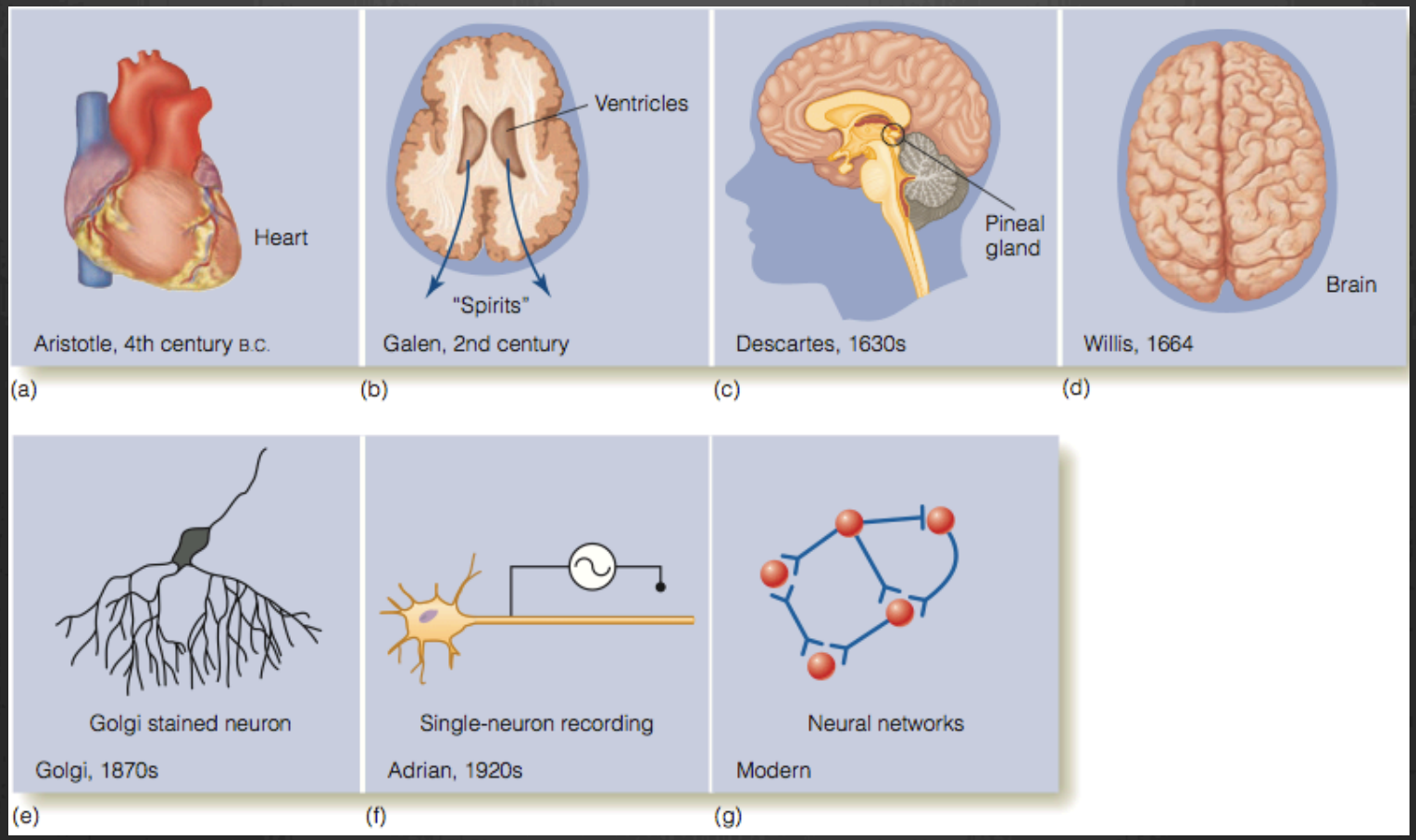


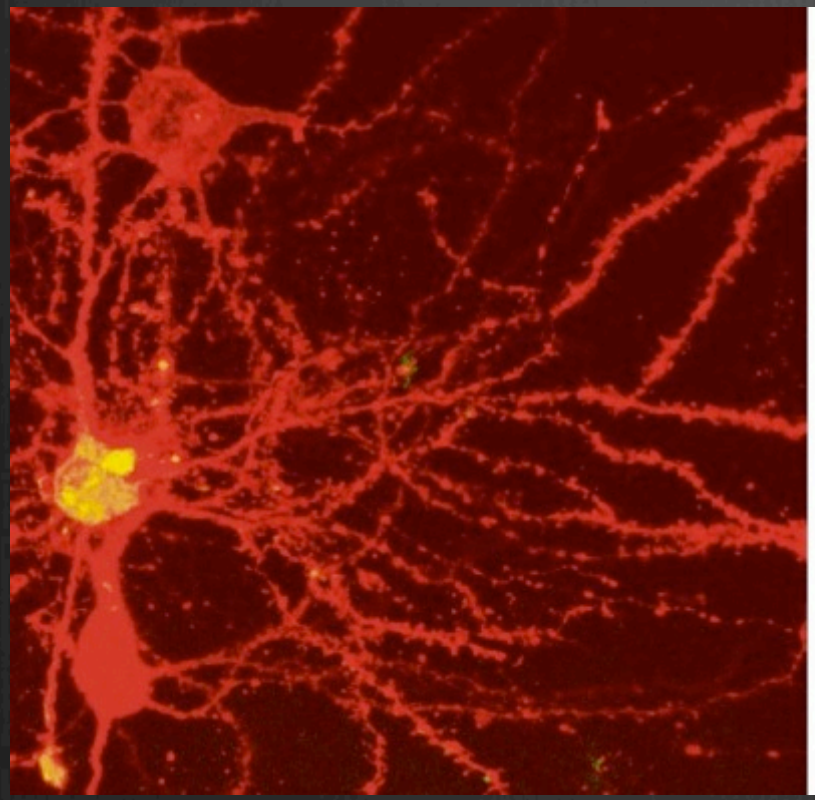
Outline

- Introduction to brain and motor control
- What is TMS?
- How does it work?
- Why do we use it?
- How do we use it?

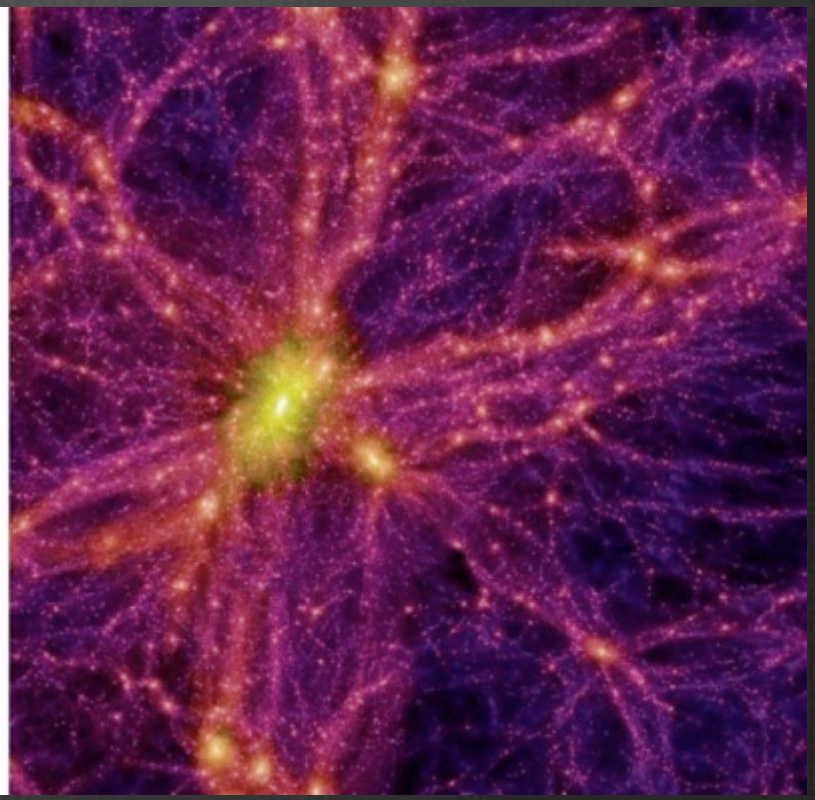
Brief history of physiology of mind



Brain Cell



The Universe



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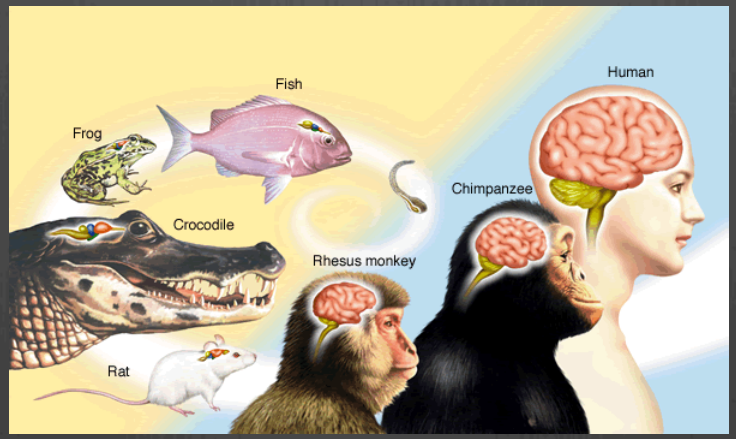
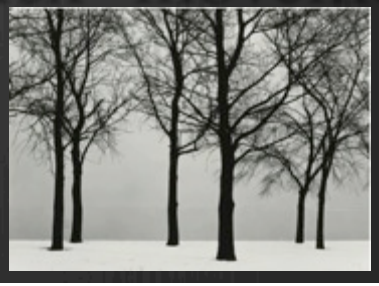
Why do we have brain?



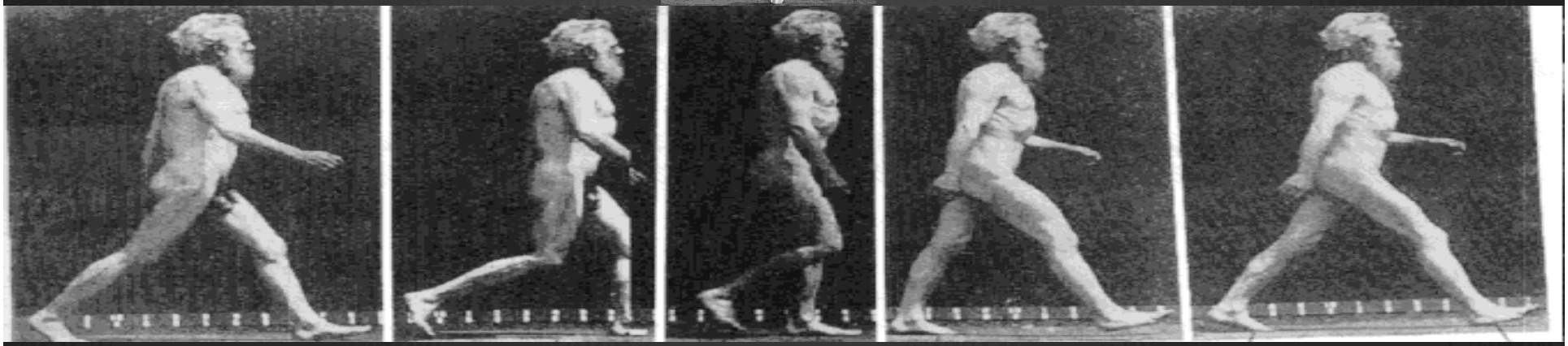
- To produce adaptable and complex movement.
- The only way we can affect the outside world is trough contractions of muscles.
- Tree doesn't require complex movements. It hasn't developed a brain.



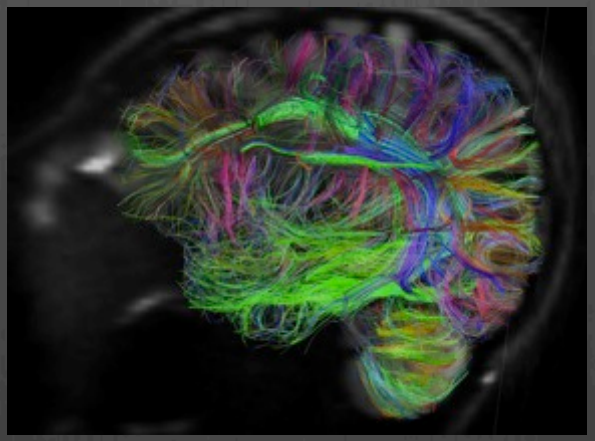
Humble Sea Squirt

The Motor system

- The motor system allows us to plan, coordinate, and execute every action that is needed to survive in the physical world.

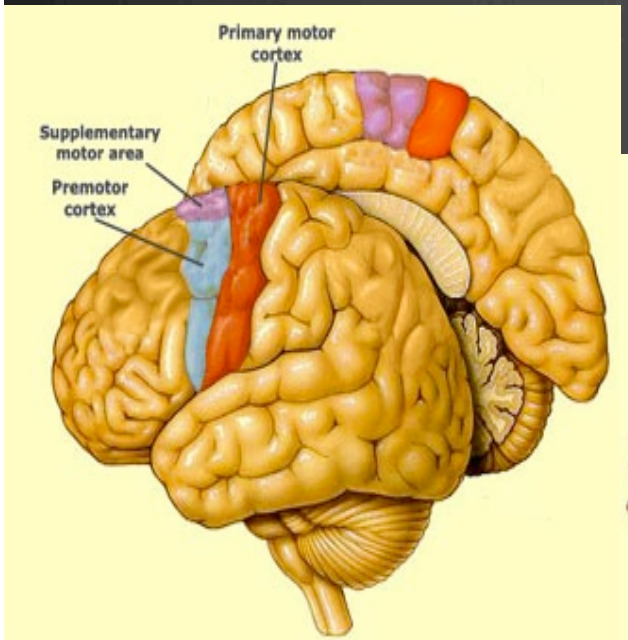


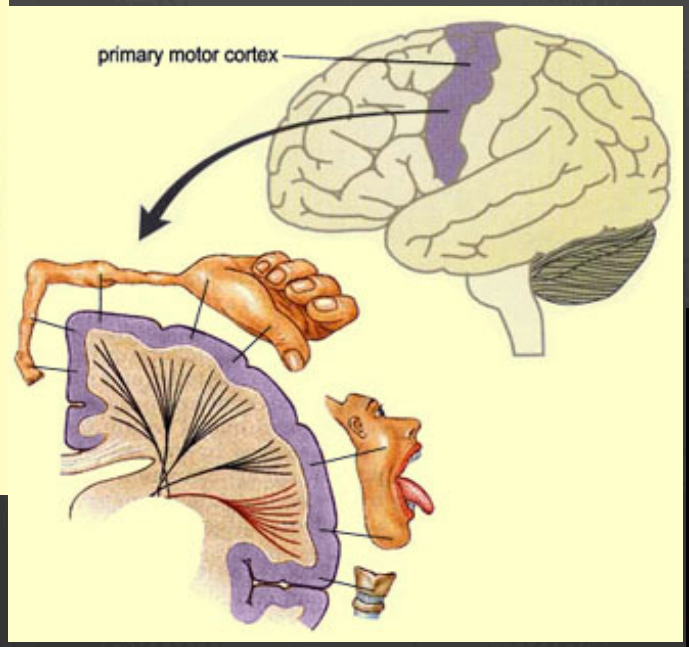
How does the brain do it?



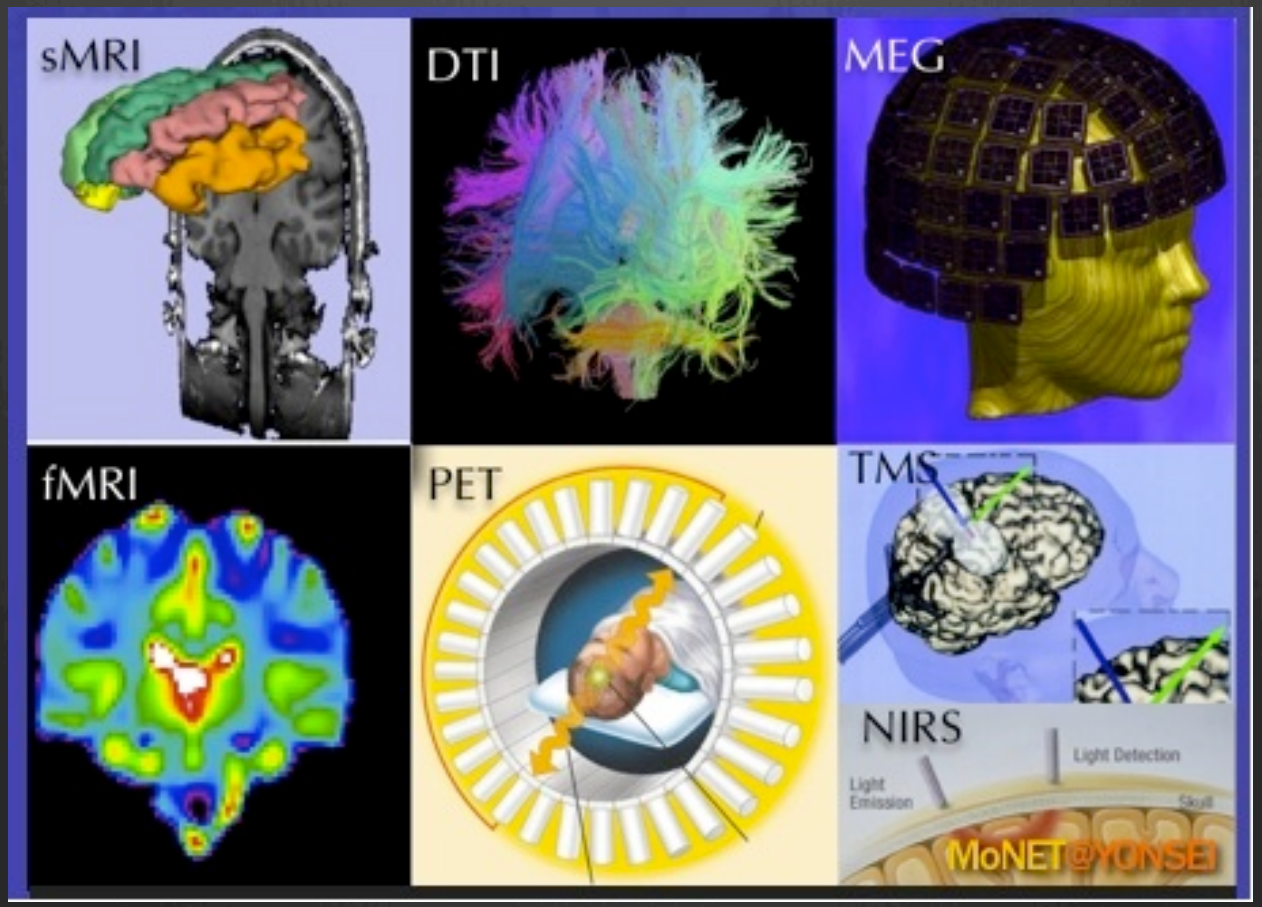
- How does the brain translate subjective intentions into basic physical actions?
- What happens in the brain when we learn a new skill?
- Why are some graceful and others clumsy?
- Why does practice make perfect?

The Motor Cortex



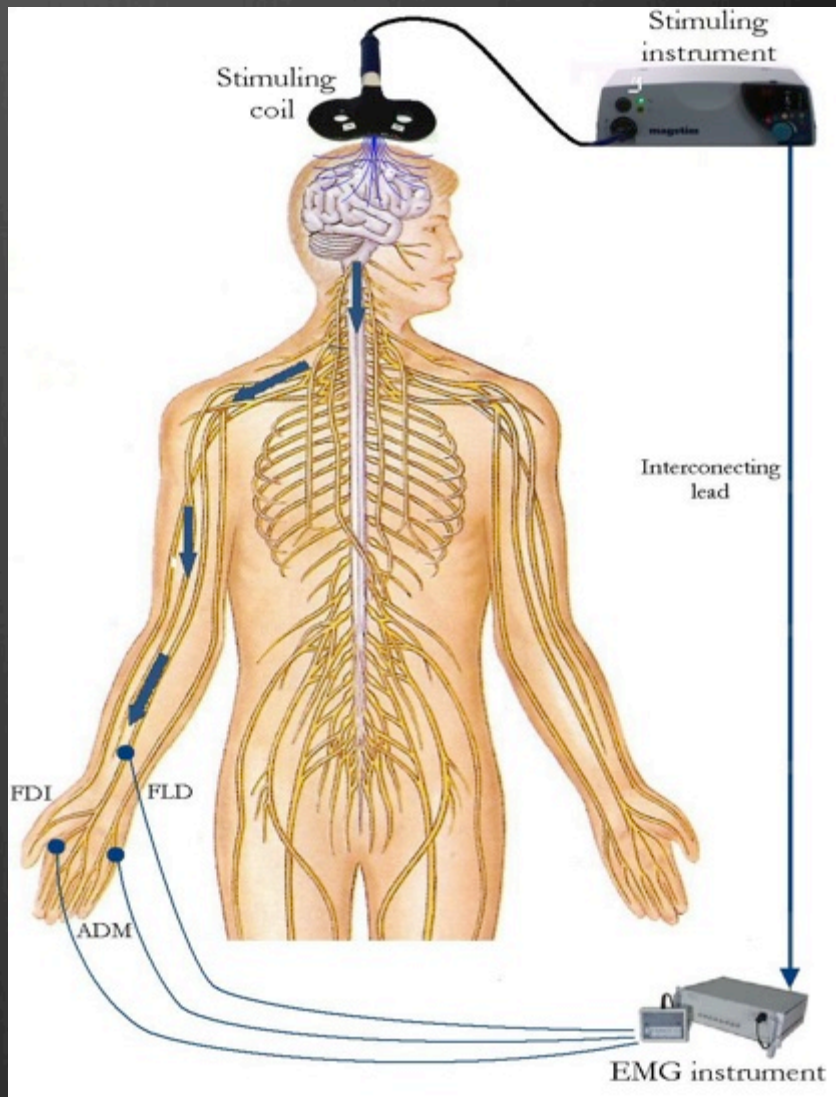


Neuroimaging

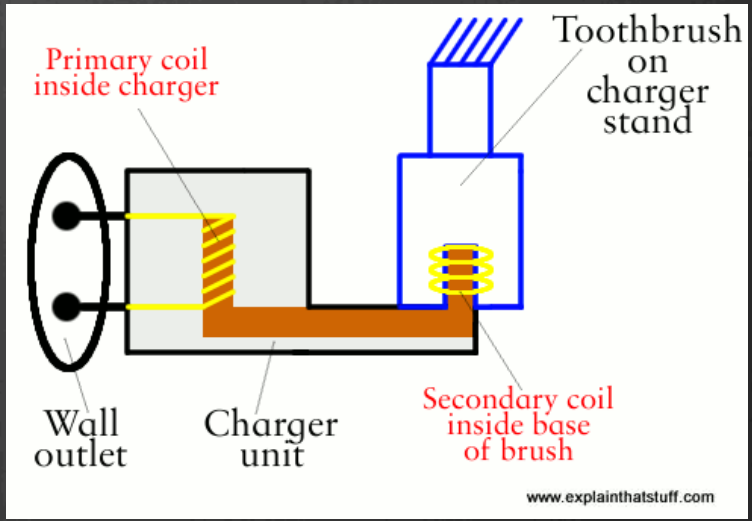


TMS background

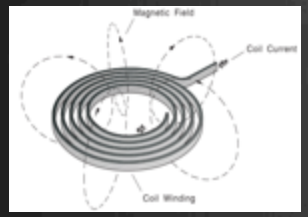
- Introduced 29 years ago
- Non-invasive tool for probing brain–behavior relationships.
- Study, diagnosis and therapy of the brain.



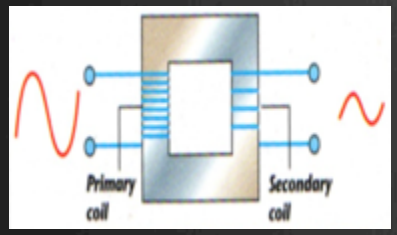
Rechargeable Electric Toothbrush



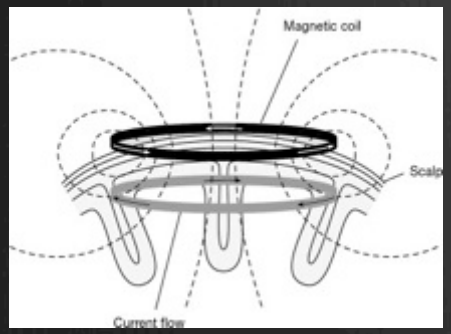
What is TMS?



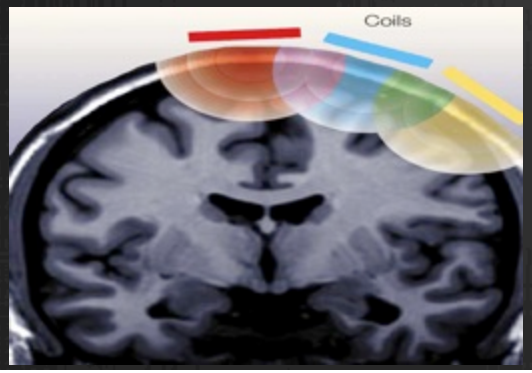
Current running trough a coil induces a magnetic field



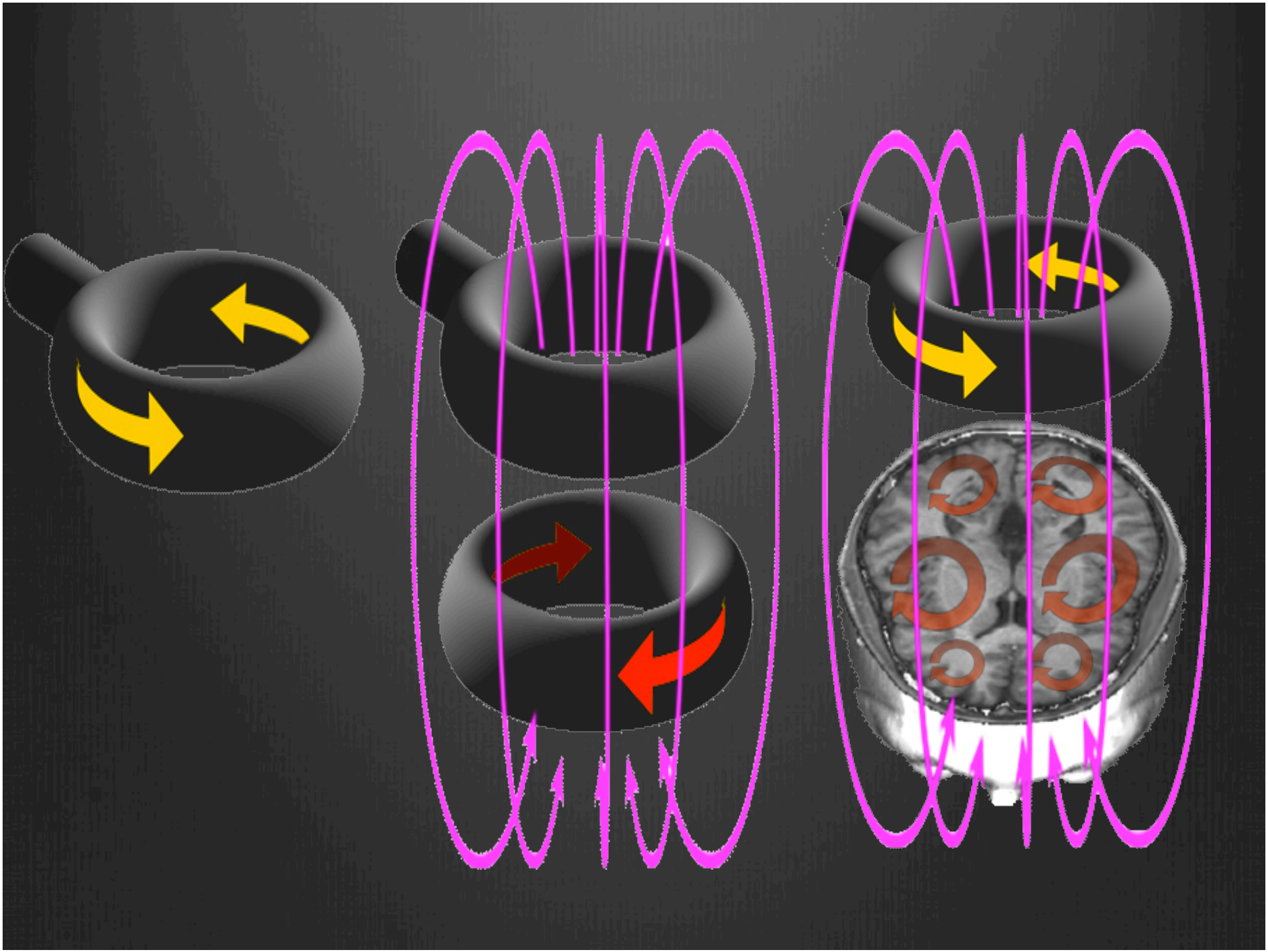
Whenever the coil on one side was connected or disconnected from a battery, an electrical current passed through the coil on the other side.

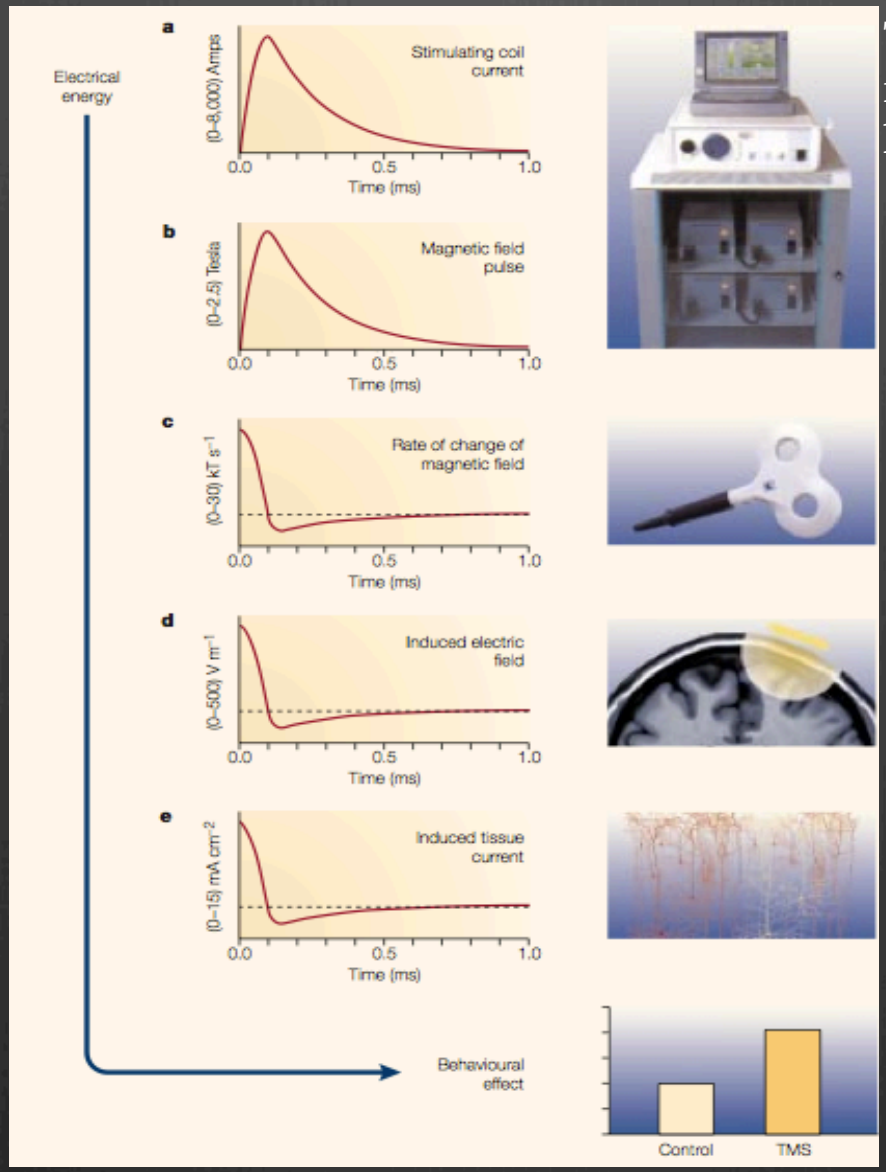


If that magnetic field is changing it can induce a current to a nearby conductive material.



With non-invasive magnetic stimulation the stimulating coil acts as the first coil and the brain as the second coil.

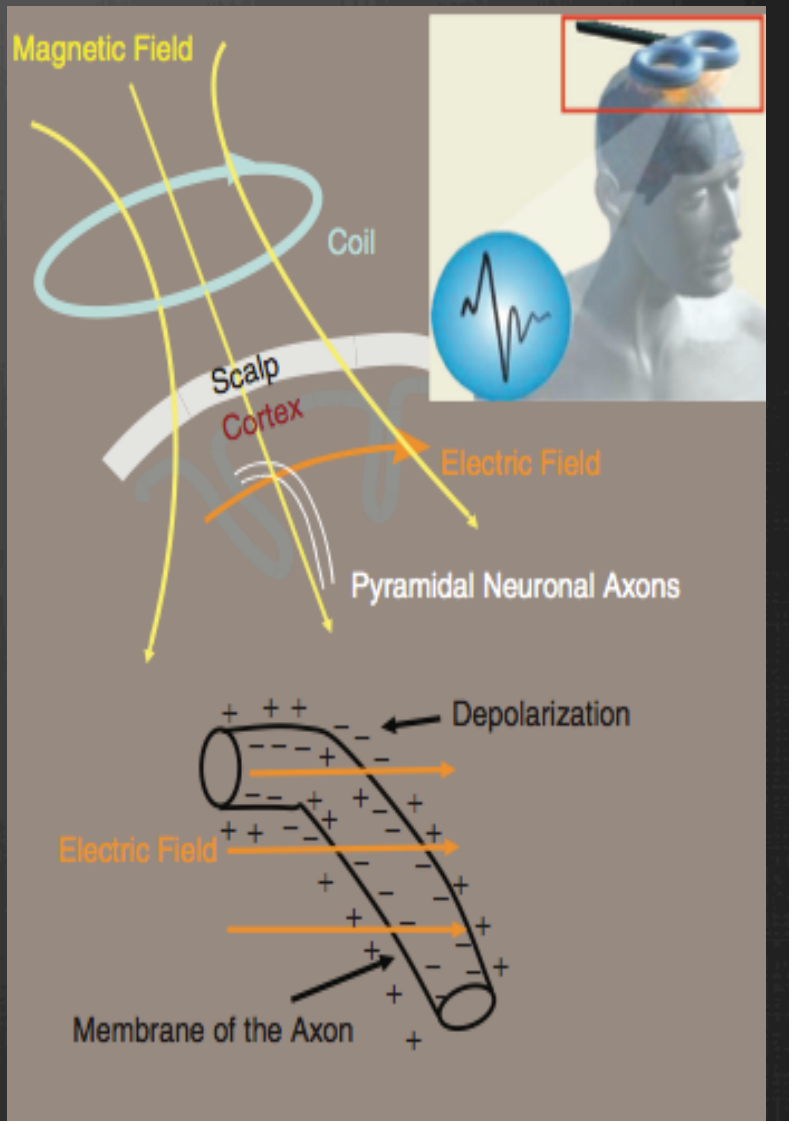




The technique riles on a peak in a current in the coil which happens at around 0.1 ms.

How does TMS work?

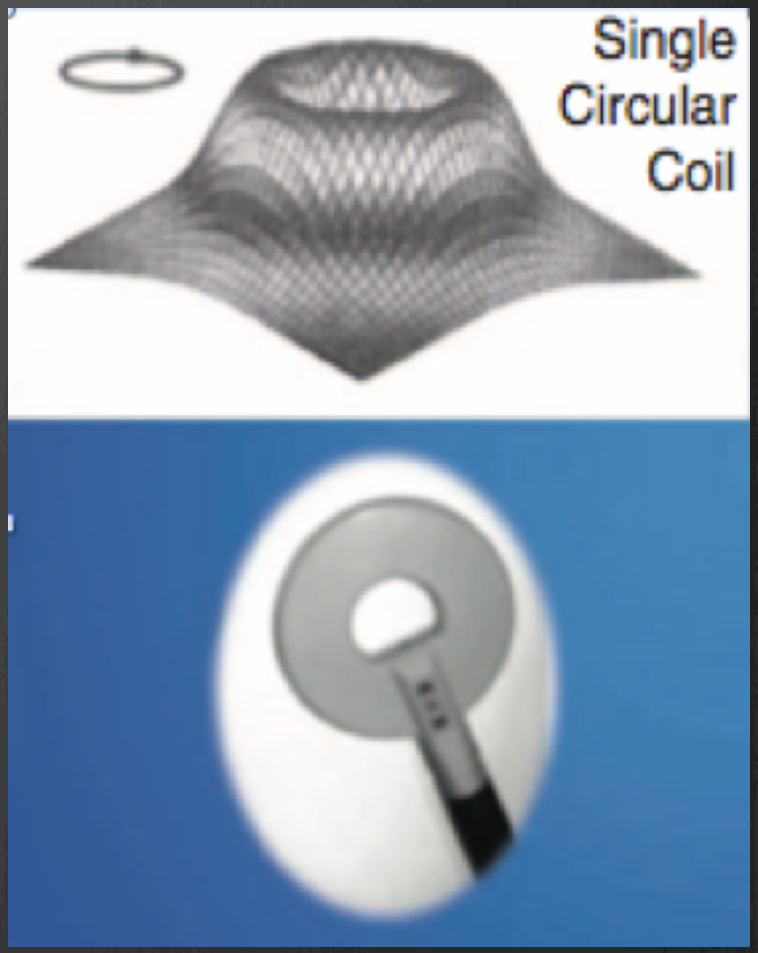
- A brief, high-current pulse is produced in a coil of wire, called the magnetic coil.
- A magnetic field is produced perpendicularly to the coil
- The magnetic field can reach up to about 2 Tesla and typically lasts for about 0.1 ms.
- An electric field is induced perpendicularly to the magnetic field.
- The electric field in the cortex caused the movement of ions and the neurons responses by firing an action potential.



Action potential

Magnetic Coils
"Round coil"

- The induced current is maximum near to the edge of the coil
- Have a good penetration of the signal into the cerebral cortex
- The coil is commonly placed at the cranial vertex, both hemispheres are stimulated not evenly but simultaneously



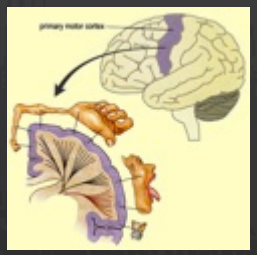
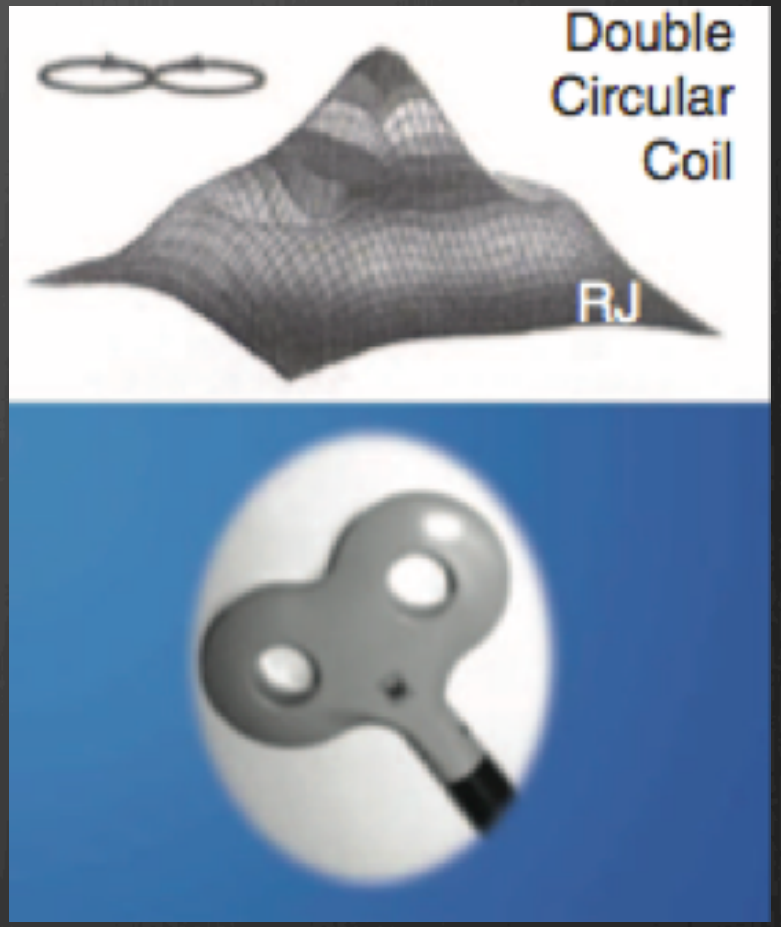
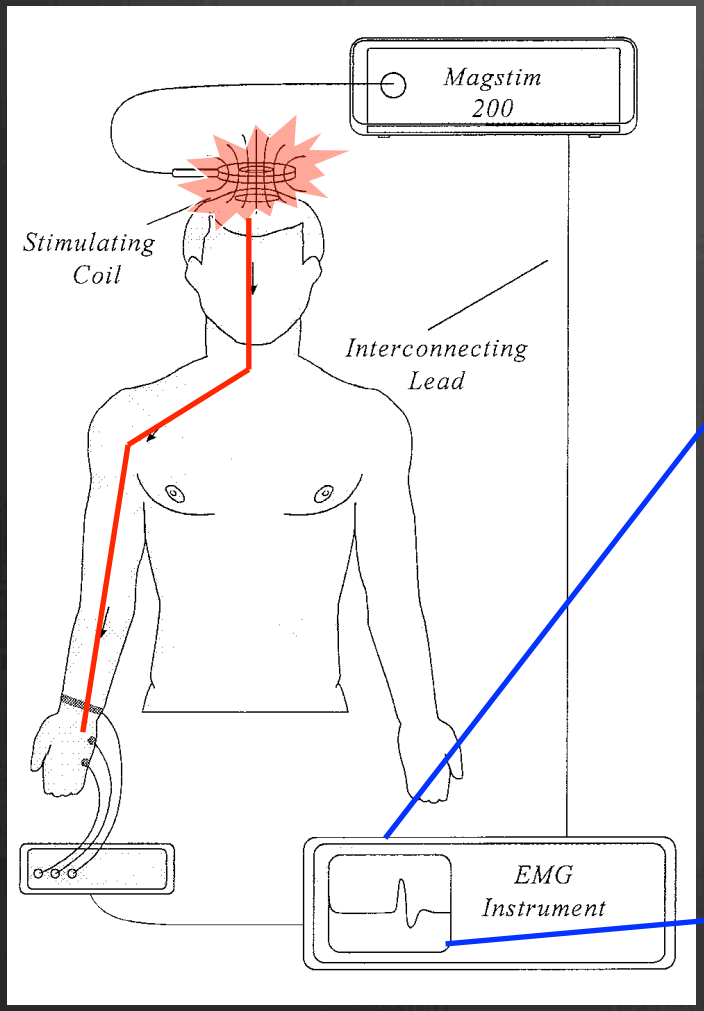


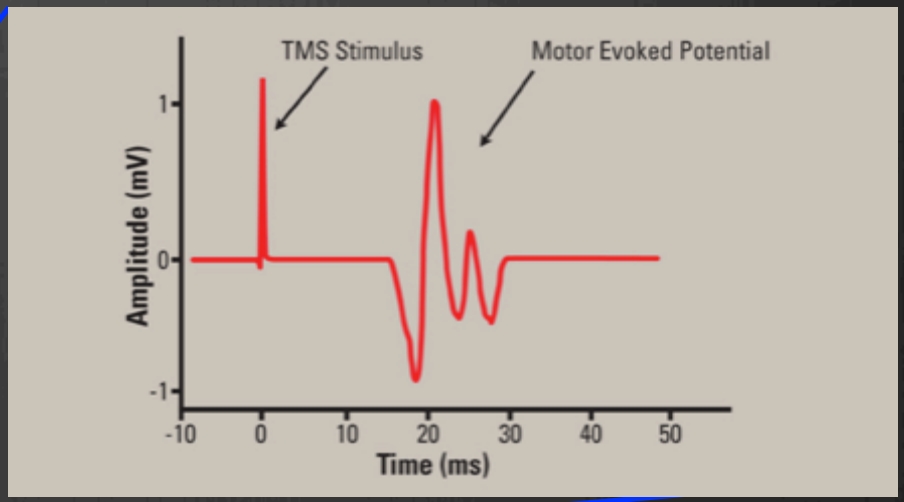
Figure 8 coil

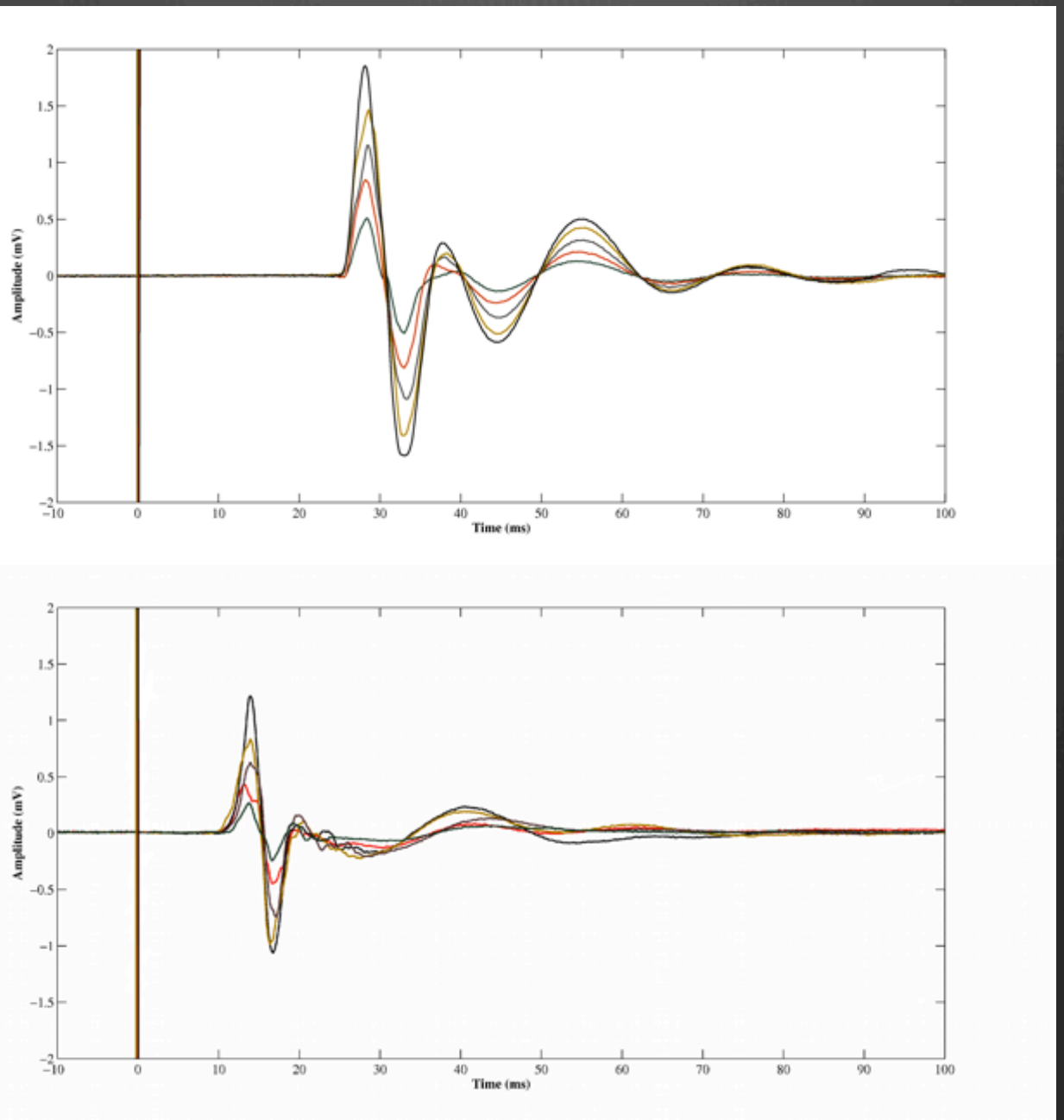
- The current flow have the same direction at the junction point
- The induced electric fields tend to be maximum below the junction
- This coils are used more in research and clinical applications
- Figure 8 coil is more focal
- However penetration tends to be more limited compare to a circular coil



TMS-EMG

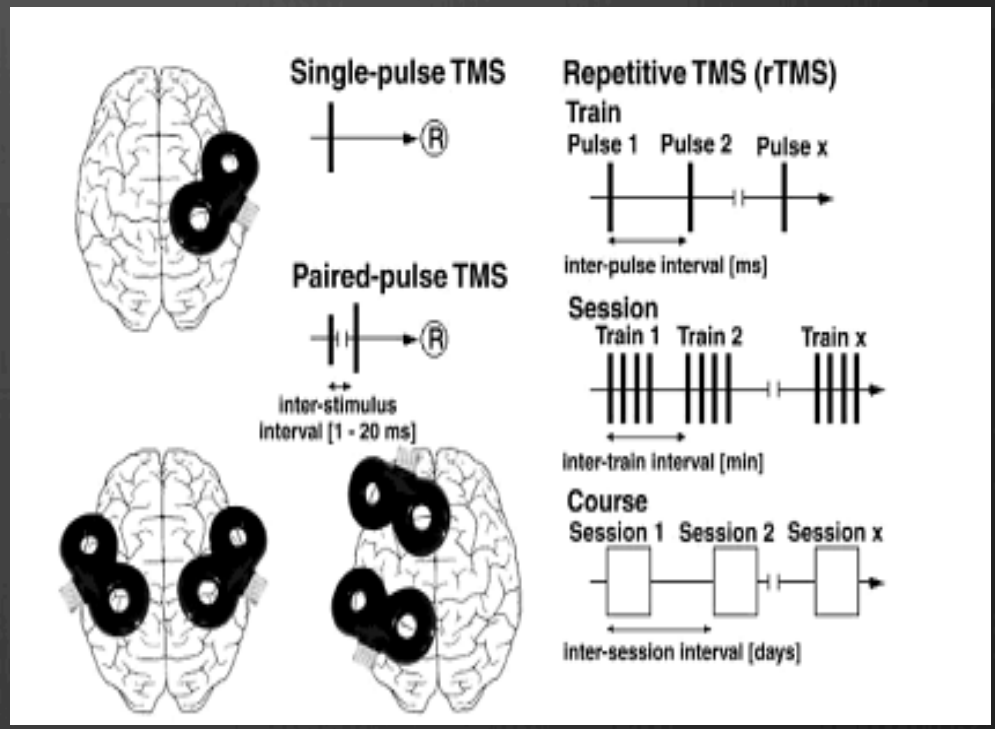

Magstim
200
Stimulating
Coil
Interconnecting
Lead
EMG
Instrument


TMS Stimulus
Motor Evoked Potential
Amplitude (mV)
1
0
-1
-10
0
10
20
30
40
50
Time (ms)


Amplitude (mV)
Time (ms)
Amplitude (mV)
Time (ms)

What different kinds of TMS are there?

- **Single pulse TMS**: stimulation is delivered once every few seconds
- **Paired pulse TMS**: two TMS pulses are fired very close together in time to see how they interact.
- **Repetitive TMS (rTMS)**: trains of pulses are delivered at a rate varying from once per second to 50 or even 100 times per second:
- low frequency (<1 Hz) causing inhibitory effects
- high frequency (>1 Hz) causing facilitatory effects



What is TMS used for?

- Is used for both clinical and research purposes.
- **Clinically**: used as a diagnostic tool to assess whether the nervous system is working properly.
- TMS is applied to the primary motor cortex and the speed with which a muscular response occurs is measured.
- rTMS: treatment tool for migraines, strokes, Parkinson's disease, dystonia, depression and auditory hallucinations.

What is TMS used for?

- In cognitive neuroscience research: TMS is used to determine how the brain controls our behavior.
- Single-pulse TMS: to activate muscles of the body and assess the state of the motor system in different experimental conditions.
- Paired-pulse TMS: how different parts of the brain are connected together.
- single-pulse and rTMS: to interfere with the activity of a small area of the brain, so we can see how behavior is affected (virtual lesion technique).

Mirror Neuron

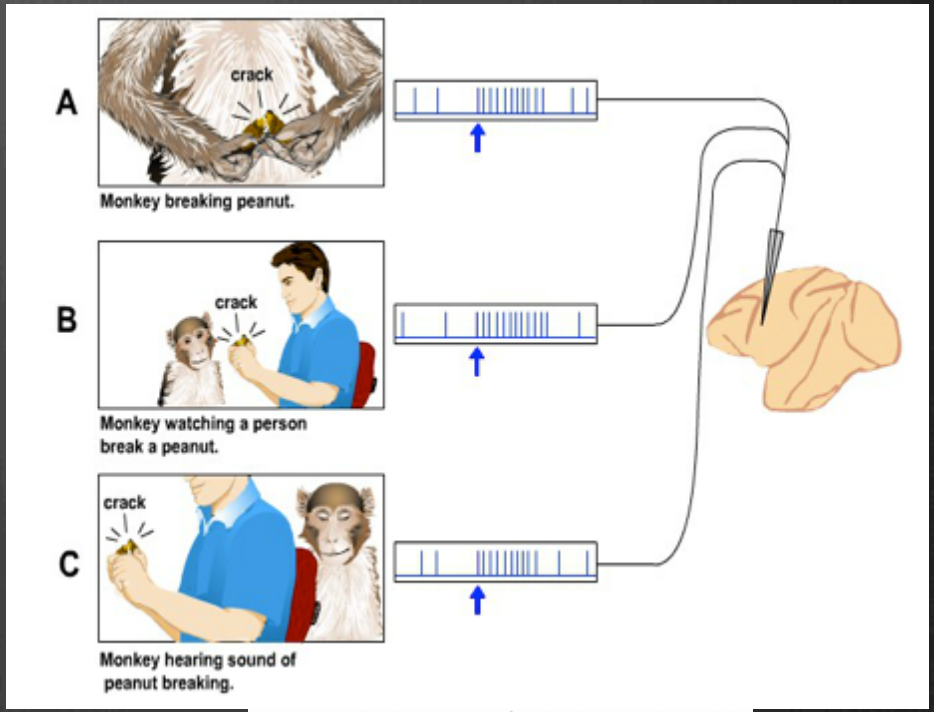
Link the production and perception of action.

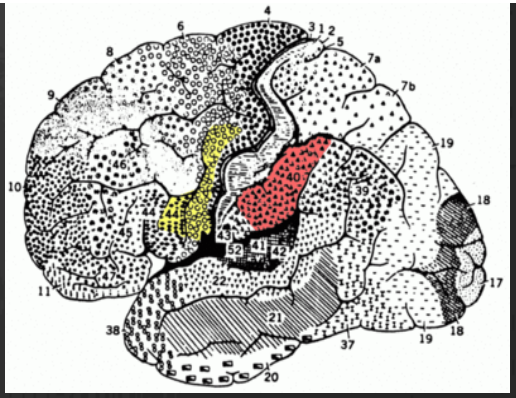
First observed in the ventral premotor area F5 of macaque monkeys. (Rizzolati et al, 1996)

The same neuron fires when an animal acts and when the animal observes or hears the same action performed by another.

Have been observed in humans.

Is involved in understanding others' actions and intentions.





Muscle specific activation for movement and amplitude

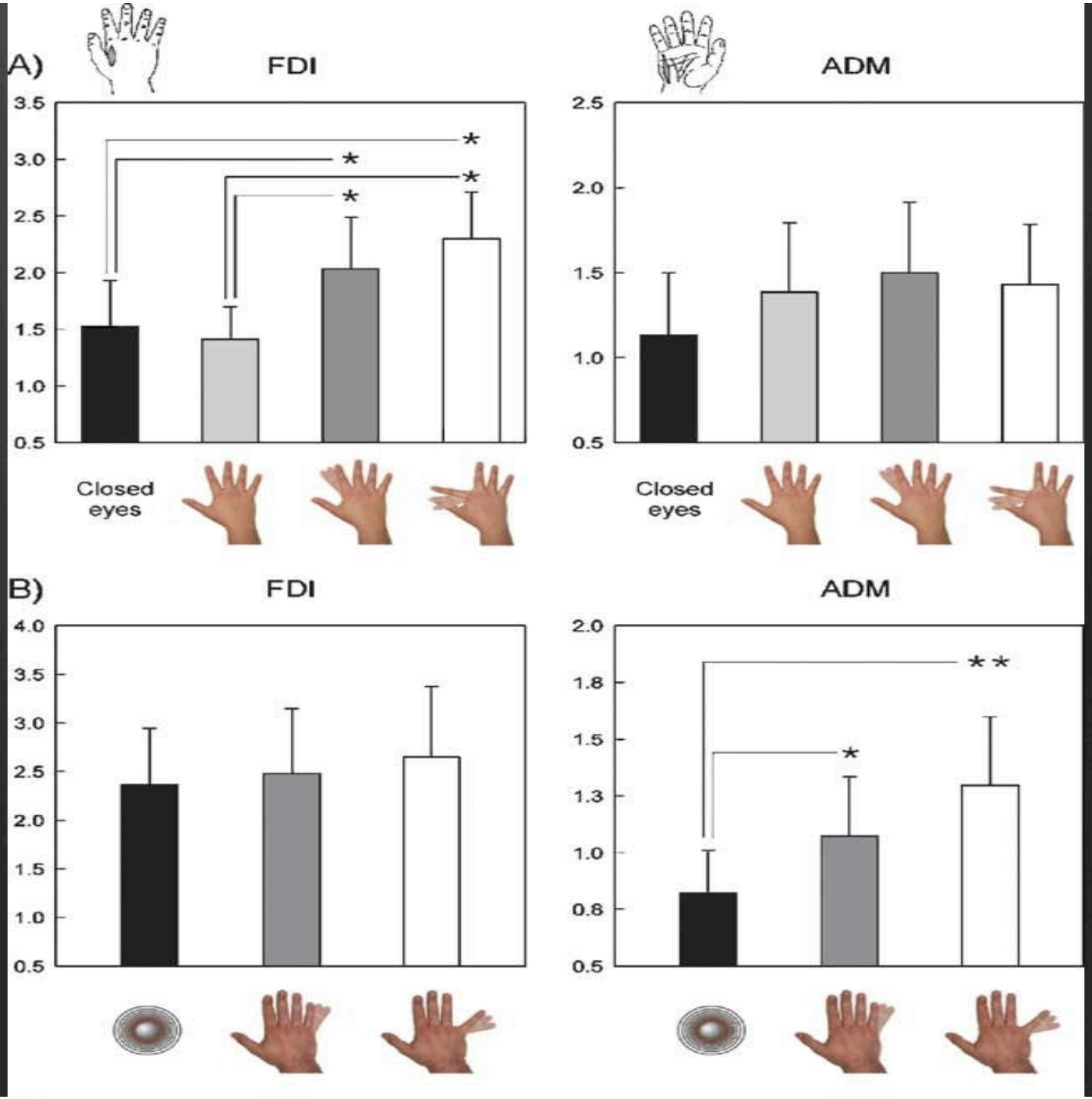
FDI

ADM

Fixed Normal Amplitude Extra Amplitude

Romani, M. Cesari, P. Urgesi, C. Facchini, S. Aglioti, S. M., (2005). Neuroimage

MEP


A)
FDI
ADM
3.5
3.0
2.5
2.0
1.5
1.0
0.5
*
*
*
*
Closed eyes
Closed eyes
B)
FDI
ADM
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
2.0
1.8
1.5
1.3
1.0
0.8
0.5
**
*

Force requirements of observed object lifting

EMPTY BOTTLE

HALF FULL BOTTLE

FULL BOTTLE

- Transcranial Magnetic Stimulation (TMS) while participants were listening to speech.
- Facilitation of motor cortex excitability in the tongue (Fadiga et al. 2002)

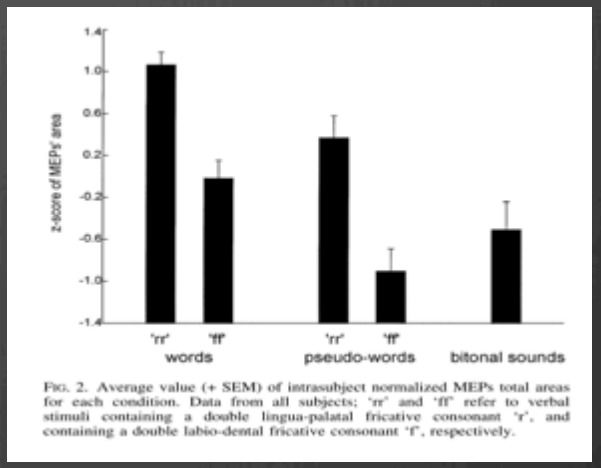
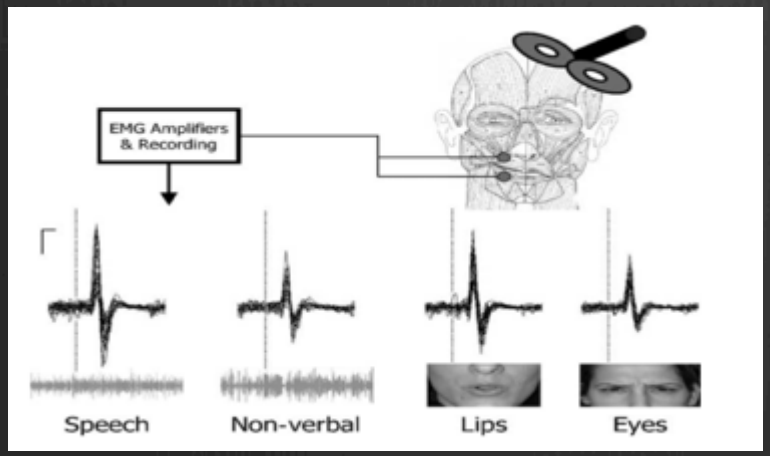


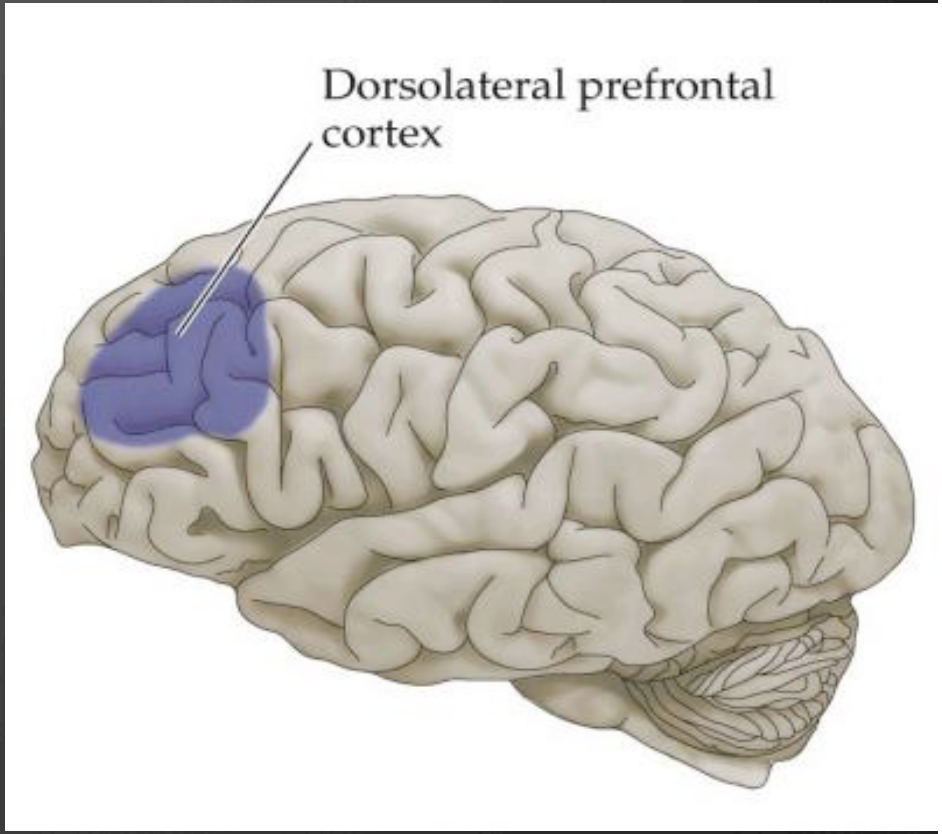
FIG. 2. Average value (+ SEM) of intrasubject normalized MEPs total areas for each condition. Data from all subjects; 'rr' and 'ff' refer to verbal stimuli containing a double lingua-palatal fricative consonant 'r', and containing a double labio-dental fricative consonant 'f', respectively.

- and lip (Watkins et al. 2003)



Efficacy of rTMS in major depression

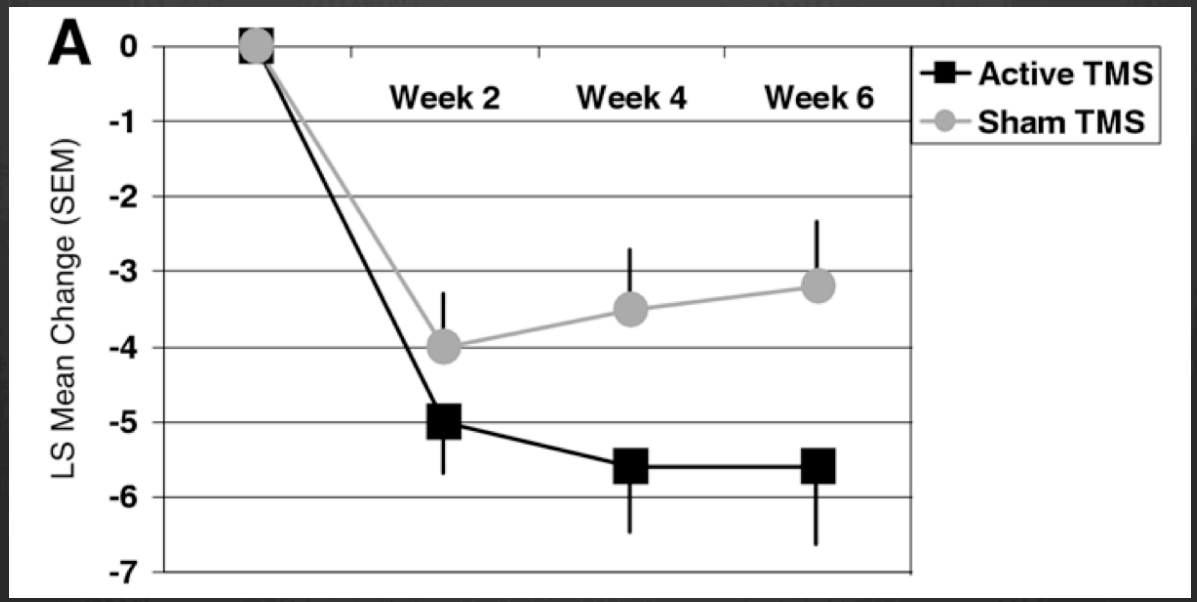
- Low levels of activity in the left dorsolateral prefrontal cortex (DLPC). High frequency rTMS
- Elevated levels of activity in the right DLPC. Low frequency rTMS
- SPECT, PET and fMRI studies.



(Bench et al 1992; Drevets et al 1997; George et al 1994; Royall 1999; Videbech et al 2002).

- Left DLPFC rTMS 5 days per week, 4-6 weeks
- 10 Hz rTMS (120% rMT), 4 sec on, then 26 sec rest
- Sham rTMS:The coil angle is 45° from the scalp. This produced the same sounds and feeling of 'knocking on the scalp', but without the brain stimulation.

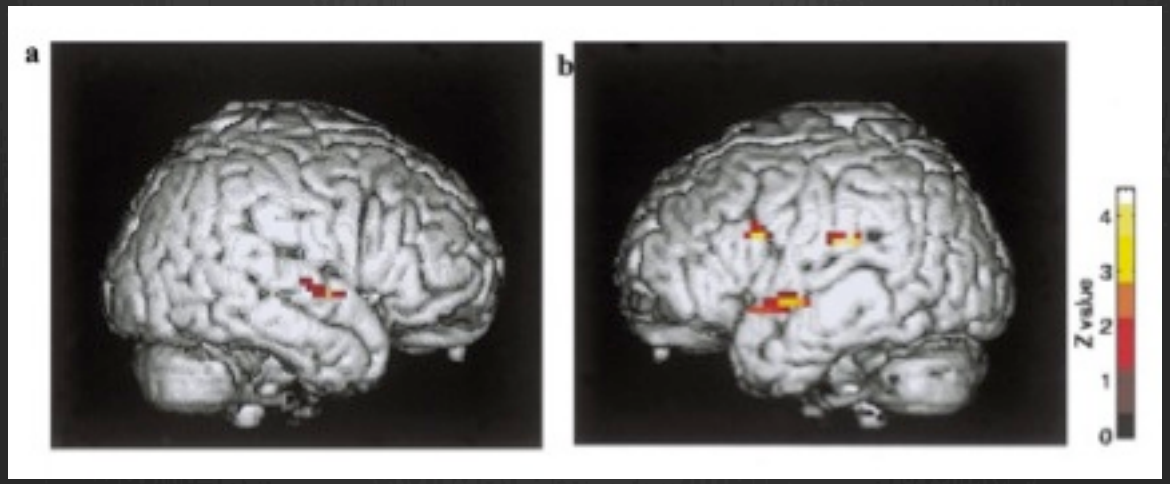
O'Reardon et al (2007)



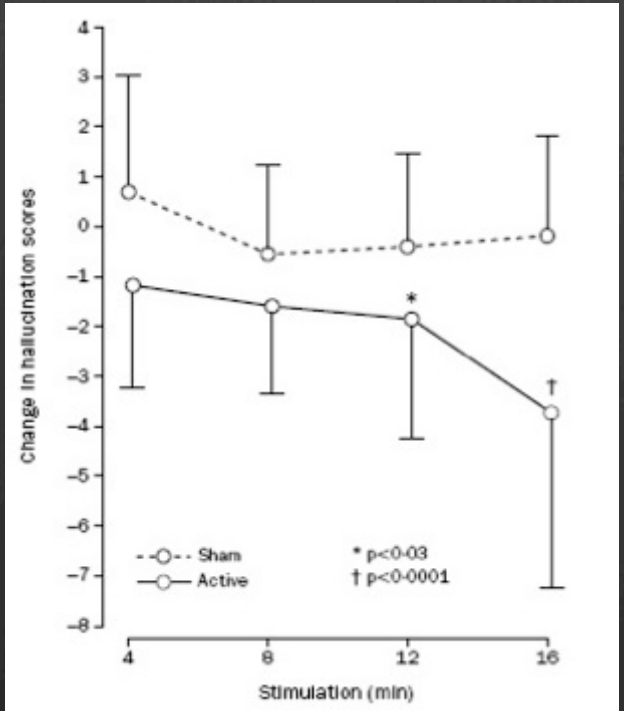
Significant reduction of Hamilton Depression Ratting Scale HDRS scores.

rTMS and auditory hallucinations in schizophrenia

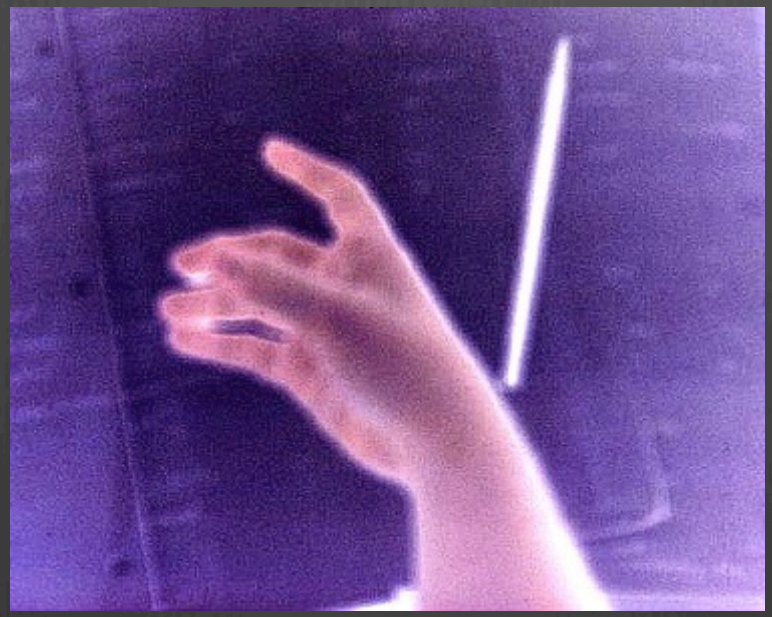
- Is a form of hallucination that involves perceiving sounds without auditory stimulus.
- Auditory Hallucinations (AH) occur in 60 – 80% of people with Schizophrenia (Hoffman et al., 2005)
- Neuroimaging studies show that primary auditory cortex is activated in hemisphere dominant for handedness during AH.



- rTMS (1 hertz) low frequency
- Right handed patients for up to about 15min a session for about 1-2 weeks
- Hallucinations Rating Scale (AHRS) assessed after treatment and sham conditions.
- AH were significantly reduced in active compared to sham condition



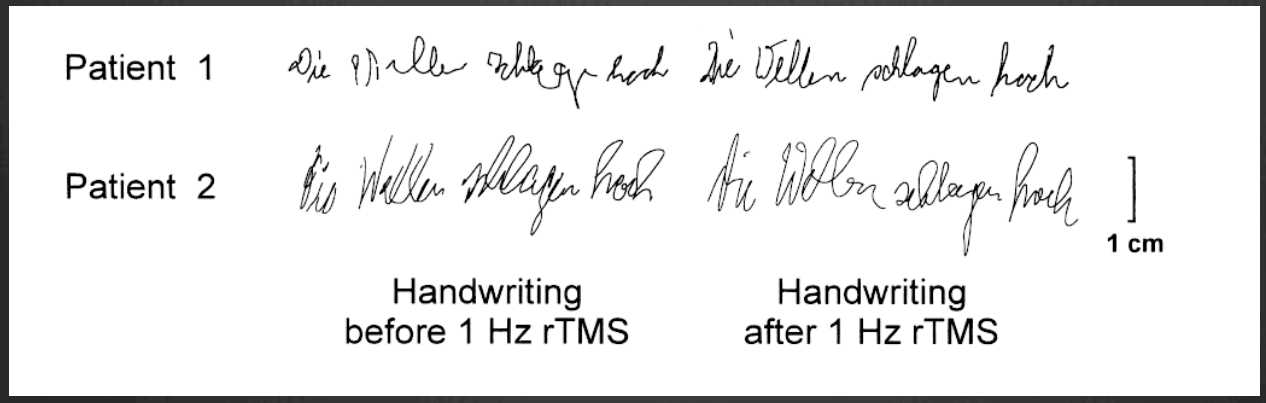
rTMS and writer's cramp



- Writer's cramp is a form of task-specific focal dystonia.
- The patient experiences uncontrolled, tiresome or tedious muscular contraction that causes altered movements and abnormal position or attitudes of hands and fingers

- Cortical excitability of the primary motor cortex is abnormally enhanced in patients with writer's cramp. low-frequency rTMS (1 Hz)

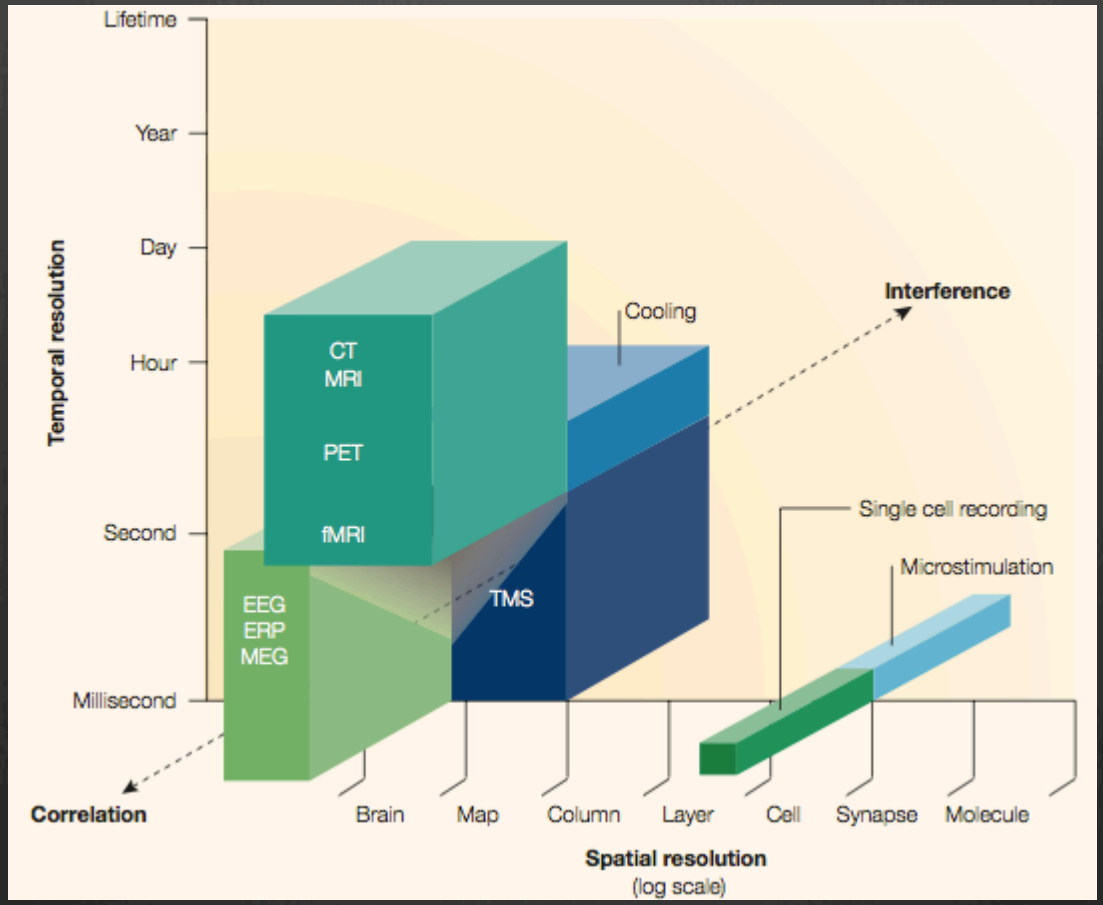
Siebner et al 1999



Before and 20 minutes after

Significant reduction of mean writing pressure which was associated with clear but transient improvement patients.

Comparison with other techniques



TMS

Advantages	Disadvantage
Non-invasive	Limited to the brain area
Interference	Discomfort
Temporal specificity	Restriction on use
Relatively inexpensive	

Question