EEG, MEG and neuromodulatory approaches to explore cognition: Current status and future directions.

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Presented By :
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Link to paper : https://www.sciencedirect.com/science/article/pii/S0278262620302803?via%3Dihub

Paper Focus Points:

- How non-invasive brain stimulation (NIBS) methods might better apply to certain cognitive functions or understand their relative efficacy for improving cognitive function ?
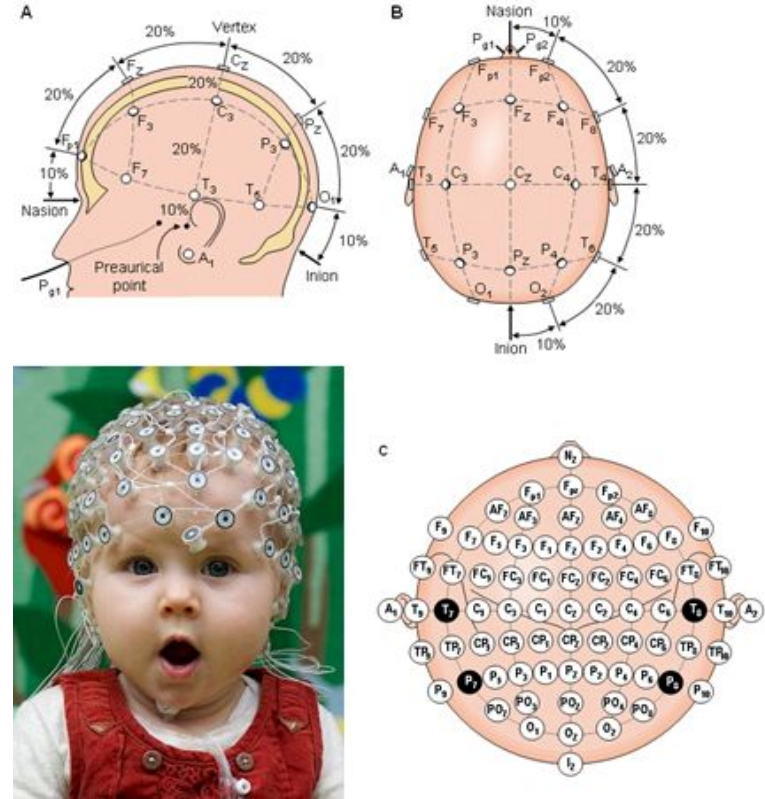
Cognitive Function

Six principle domain of Cognitive Functions:

1. Complex attention
2. Executive Function
3. Learning and Memory
4. Language
5. Motor Function
6. Social Cognition

Image Source :https://www.nature.com/articles/nrneurol.2014.181
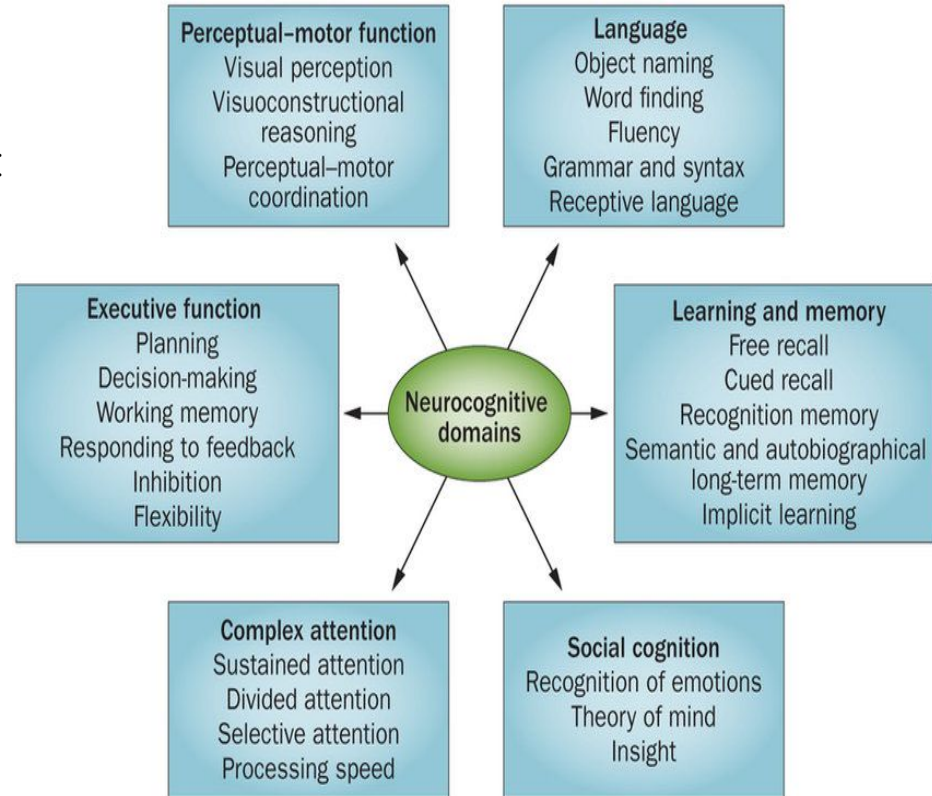
EEG : Introduction

- **Electroencephalogram** (EEG) electrodes
- Scalp recording of **electrical activity** of cortex => waveform signals
- **Microvolts** (μV) – small!
- Role of EEG in neuroimaging:
  - Identify **neural correlates**
  - **Diagnose** epilepsy, sleep disorders, anaesthesia, coma, brain death

MEG: Introduction

http://www.admin.ox.ac.uk/estates/capitalprojects/previouscapitalprojects/megscanner/

- **Magnetoencephalography**

- Direct external recordings of **magnetic fields** created by electrical currents in cortex

- Measured in **fT** to **pT**

- Role of MEG in neuroimaging:
  - **Neural correlates** of cognitive/perceptual processes
  - **Localise** affected regions before surgery determine regional and network functionality

- **Excellent spatial resolution**
  good for functional mapping of specific cortex (M1, V1) during behavioural, cognitive, perceptive tasks

- **Surgical planning** in patients with brain tumours or intractable epilepsy

- **Research** into whole-brain network connectivity
  Millisecond temporal resolution

EEG: Frequency Spectrum

- **5-50 μV**, mostly below 30 μV
- Sharp spike-waves, **light sleep** stages

| Beta (β) 13-30 Hz |
| Frontally and parietally |

- **5-120 μV**, mostly below 50 μV
- **Awake**, eyes closed, mental inactivity, physical relaxation

| Alpha (α) 8-13 Hz |
| Occipitally |

- **20-200 μV**
- Strictly rhythmic or highly irregular
- Awake & drowsiness, **light sleep** stages
- LTP and phase-encoding

| Theta (Θ) 4-8 Hz |
| Children, sleeping adults |

- **5-250 μV**
- Abnormality in waking adults, accompaniment of **deep sleep**

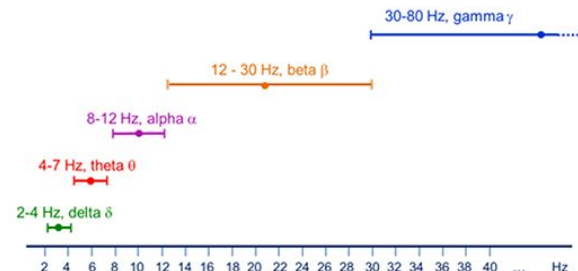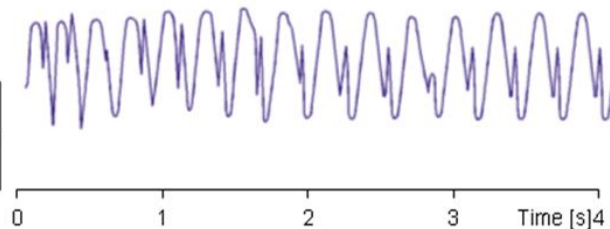| Delta (δ) 0.5-4 Hz |
| Infants, sleeping adults |

+ **Gamma waves**
31-100 Hz, 10 μV
'binding of consciousness', unity of perception

Spikes   3 Hz
Epilepsy - petit mal   200
V [μV]
100
0

Tiege and Zlobinski, 2006

30-80 Hz, gamma γ

12 - 30 Hz, beta β

8-12 Hz, alpha α

4-7 Hz, theta θ

2-4 Hz, delta δ

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 ... Hz

Major brain rhythms as classified by their frequency span.

Non-Invasive Brain Stimulation (NIBS) Techniques

- Different from the recording of brain (EEG,MEG,fMRI)
- NIBS are causations methods (which causes change in the brain) and then we measure changes in behaviour or cognition.
- Can help studying neuronal changes in ms.
- Able to detect how much effect on brain or neurons.
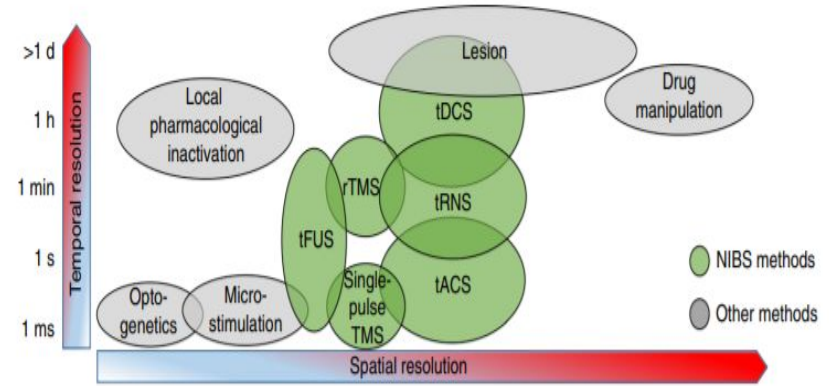
tFus:Transcranial Ultrasound Stimulation
rTMS : Repetitive Transcranial magnetic stimulation
tDCS : Transcranial Direct Current Stimulation (tDCS)
tACS : Transcranial Current Stimulation
tRNS : Tramscranial Random Noise Stimulation

Image : https://pubmed.ncbi.nlm.nih.gov/29311747/

Repetitive Transcranial magnetic stimulation (rTMS)

- Produce changes in neuronal activity in regions of the brain.
- Help to detect critical region.
- Commonly used method.
- High temporal resolution.
- Help to detect particular behaviour by identifying brain region.
- Upper-limb motor-control recovery.
- Mood control and depression.
- Decreased activity in depression.
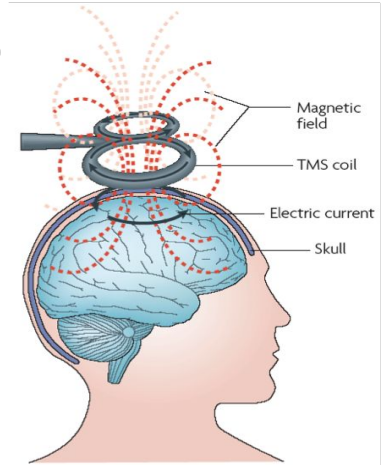
Approaches for EEG/MEG data analysis

- Time Domain Analysis : Event Related Potential
- Spectral analyses: amplitude, phase and coordination changes
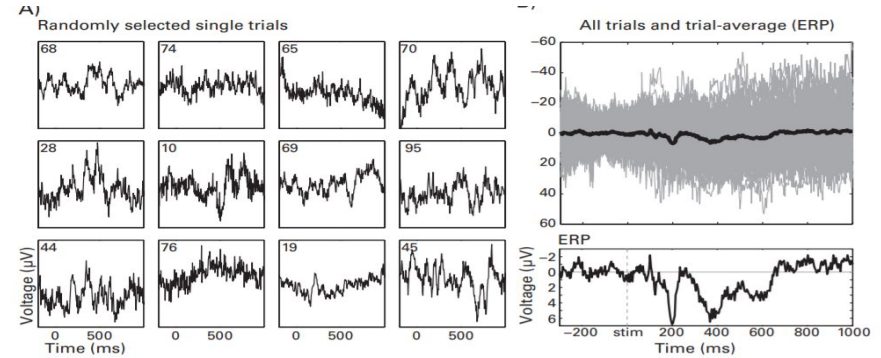- Event-related phenomena in comparison: phase-locked vs time-locked

Figure 9.1
Panel A shows single-trial EEG traces from 12 randomly selected trials (number inside plot indicates trial number). Data are from electrode FCz. Panel B shows 99 single trials in gray and their average—the ERP—in black. Panel C shows the same ERP with focused y-axis scaling.
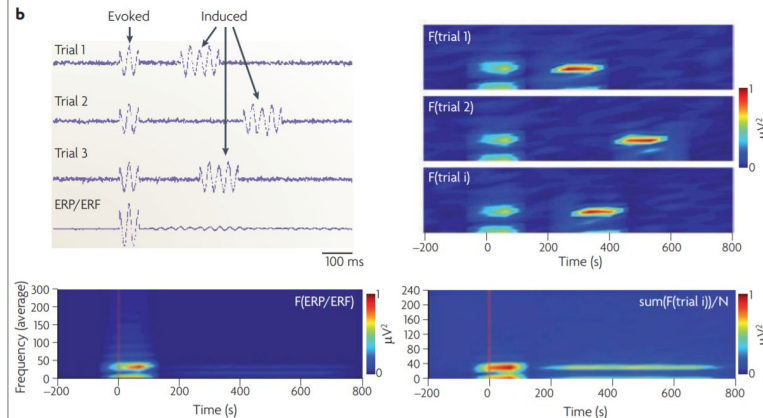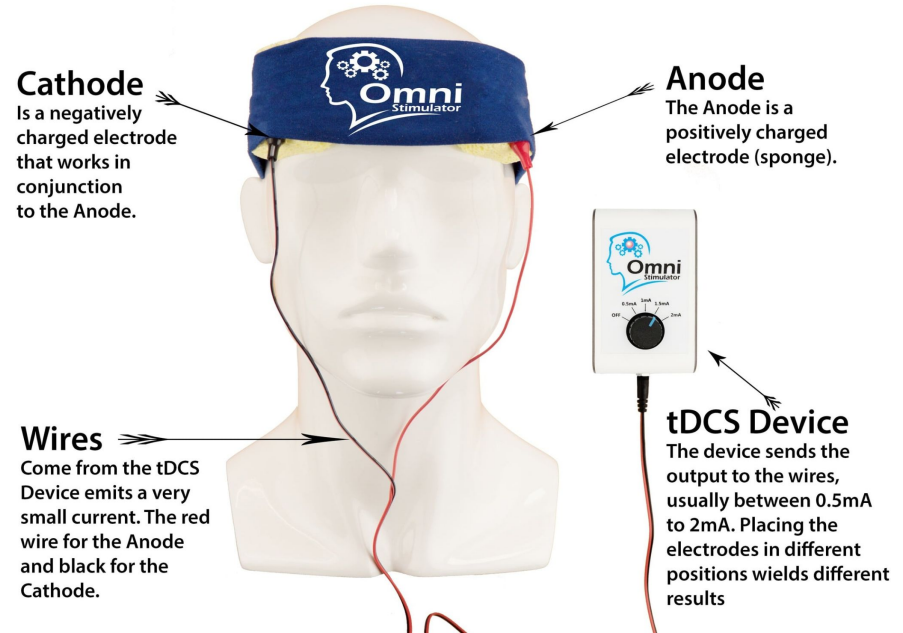
Image : https://direct.mit.edu/books/book/4013/Analyzing-Neural-Time-Series-DataTheory-and, Ch 9

Image : https://www.nature.com/articles/nrn2774.pdf

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Transcranial Direct Current Stimulation (tDCS)

- Treat a range of neuropsychiatric disorders.
- Nature of stimulation either improve cognition or make it worse.
- Constant current not time varying
- Improved the clinical motor outcome of Parkinson's patients, as measured by the fine motor-control performance of their distal upper- limb.
- Used to treat patients with higher learning deficits.
- Enhanced language acquisition and fluency in healthy individuals.

Cathode
Is a negatively charged electrode that works in conjunction to the Anode.

Anode
The Anode is a positively charged electrode (sponge).

Wires
Come from the tDCS Device emits a very small current. The red wire for the Anode and black for the Cathode.

tDCS Device
The device sends the output to the wires, usually between 0.5mA to 2mA. Placing the electrodes in different positions wields different results
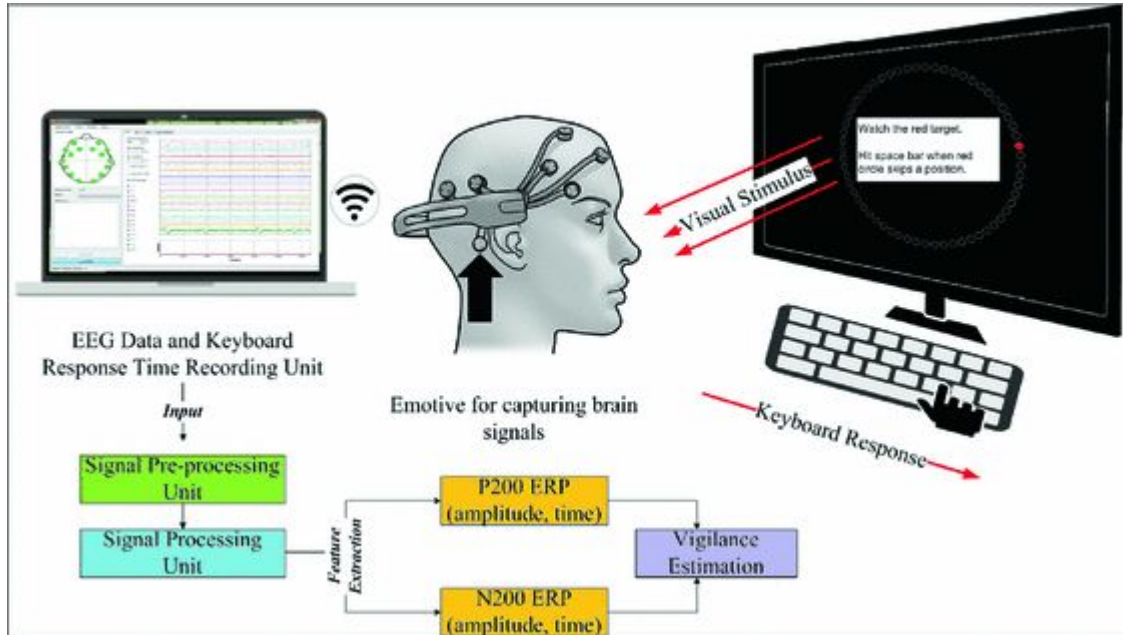
Sensory Stimulation

Image:https://link.springer.com/chapter/10.1007/978-3-319-72038-8_16

- Multiple cortical areas specialised for sensory recognition or motor execution.

- Some functional modules are participating in both sensory as well as motor processing to analyze them sensory stimulation.

- Synchronized with EEG.

Transcranial Current Stimulation (tACS)

- Alternative Current
- Directly interfering with cortical rhythms (generating rhythms).
- Theta (improve cognition).
- Alpha (improve motor performance).
- Beta (deteriorate motor performance).
- Gamma (possibly interfere with attention).
  - Ability to detect motor behaviour, attention or visual stimuli
- Helps to diagnose Parkinson's disease or schizophrenia by attenuating or resetting anomalous oscillations.
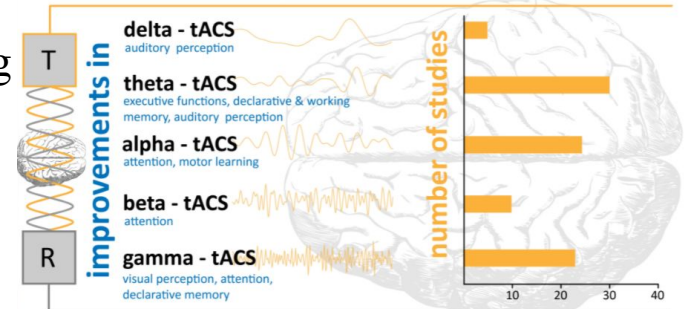

Image: https://www.mdpi.com/2076-3425/10/12/932

tACS Continued..

- tACS stimulation improves visual performance when applied at theta-band over the occipital cortex, but not when stimulating over the medial prefrontal cortex or at alpha-band.

- Improved memory performance.

- Improved behavioural performance.

- Improved visual memory-matching reaction times.

- Modulated speech comprehension.

- Electrode positioning and stimulatory in-tensity are two important stimulatory parameters that impact the efficacy.

Adverse effects

- No severe negative effects have been reported in tDCS and tACS.

- TMS (seizures and auditory damage,~5% incidence of mild adverse effects, including headache, nausea or local pain over the stimulated area).

- tDCS (Skin problems).

- tACS(none).

Conclusion

In sum, NIBS can modulate brain activity by enhancing the oscillatory coherence and synaptic plasticity, and, hence, has the potential to produce long-term therapeutic effects for different motor, language and memory disabilities.

Thank You!
Any Questions ??