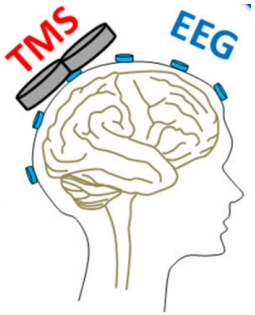
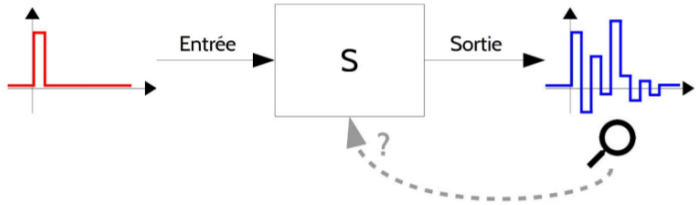
Couplage TMS-EEG : technique et applications

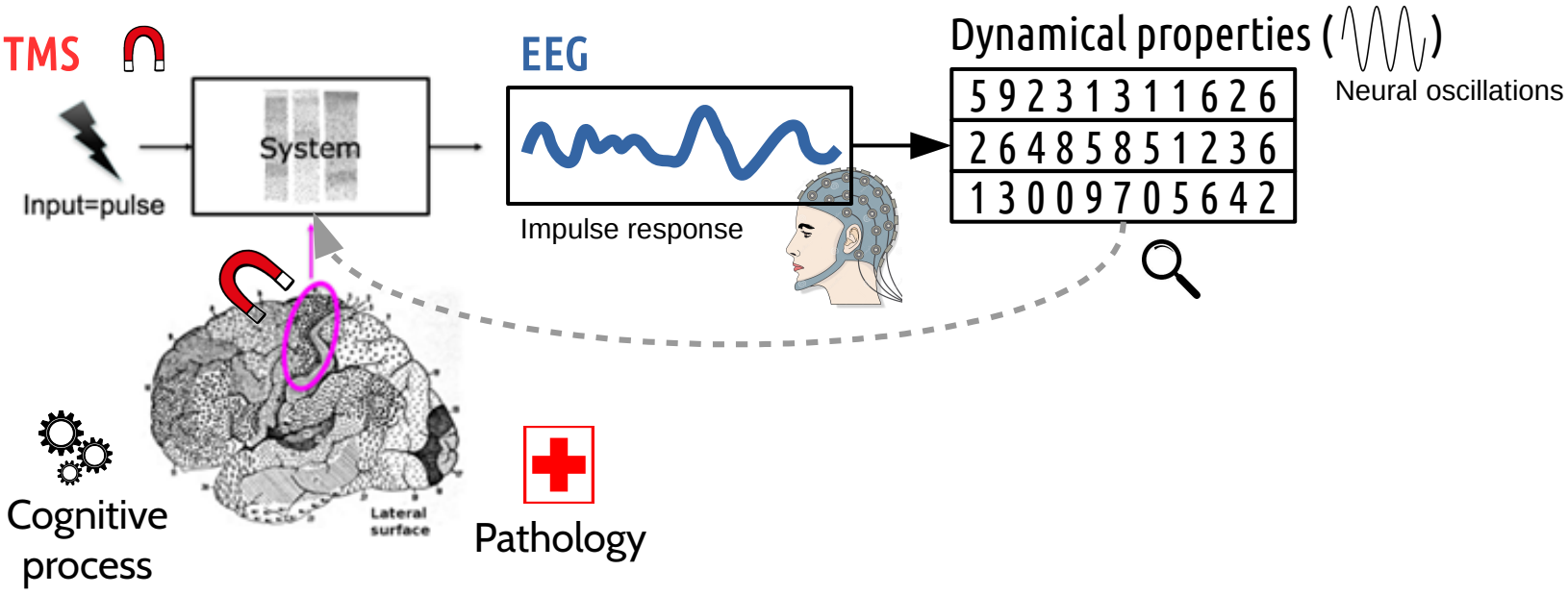


Sylvain Harquel

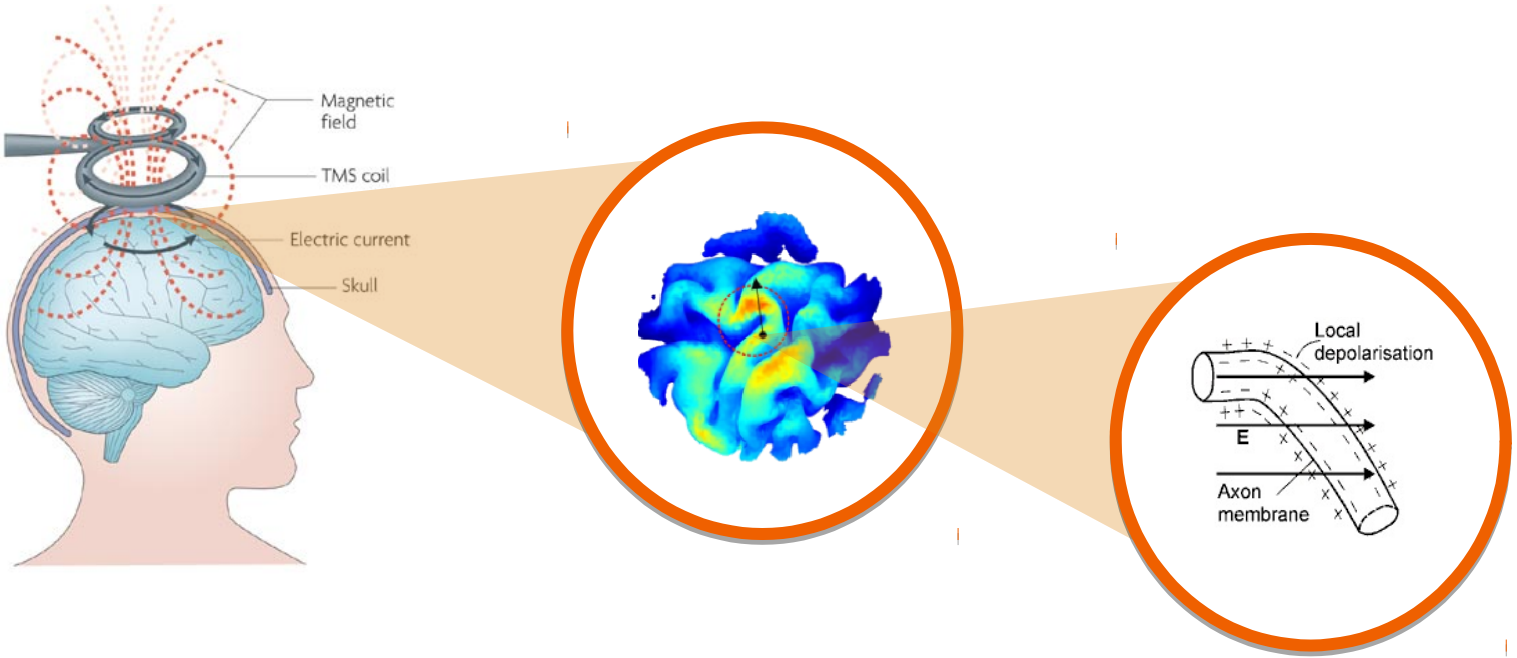
cnrs
UNIVERSITÉ Grenoble Alpes
GIN Grenoble Institut Neurosciences
iRMaGe TMS IRM NIRS EEG
LPNC Laboratoire de Psychologie et NeuroCognition

Principe général





Stimulation Magnétique Transcrânienne



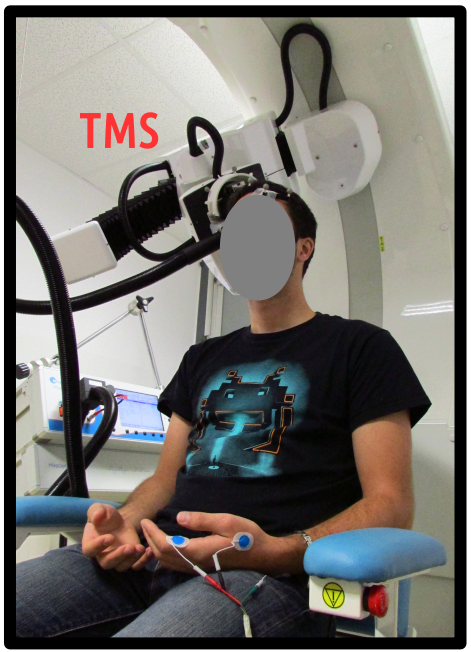
Magnetic pulse

Induced electrical field

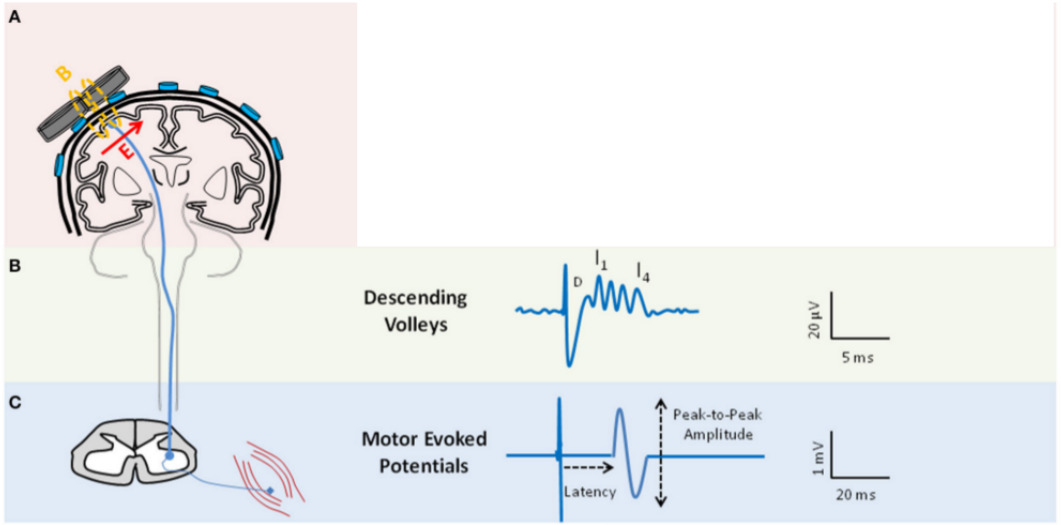
Neural activation

Ridding & Rothwell, *Nature Rev. Neurosc.*, 2007 ; Thielscher et al., *NeuroImage*, 2011

Stimulation Magnétique Transcrânienne

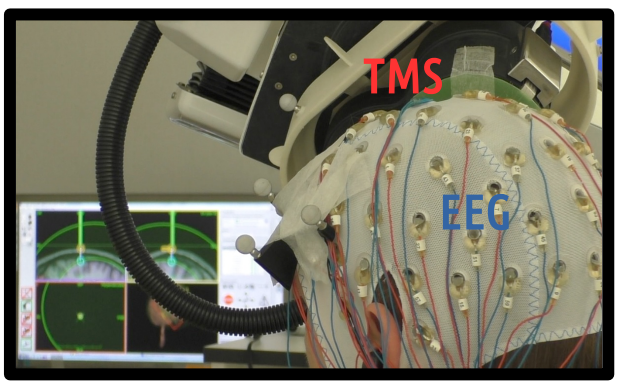


Experimental setup

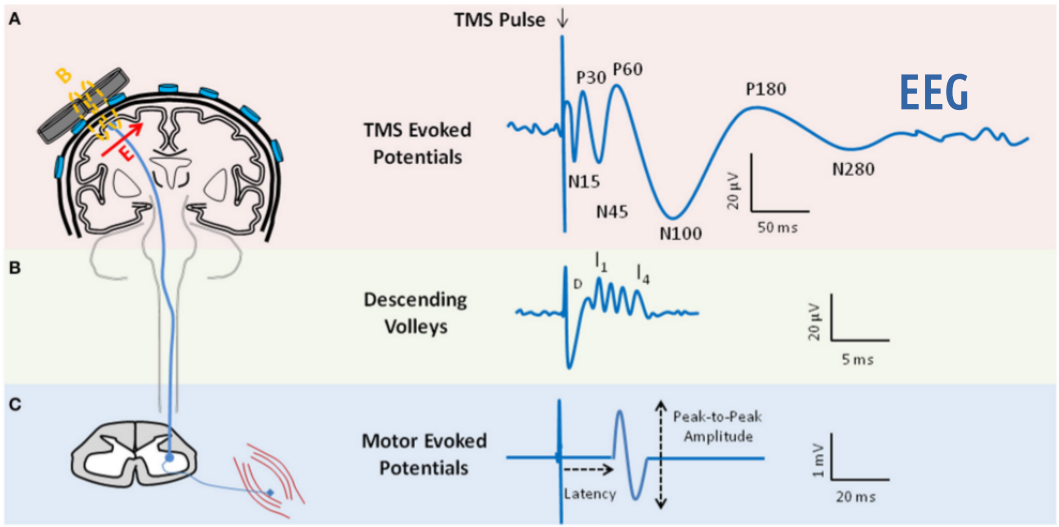


Farzan et al., *Frontiers in neural circuits*, 2016

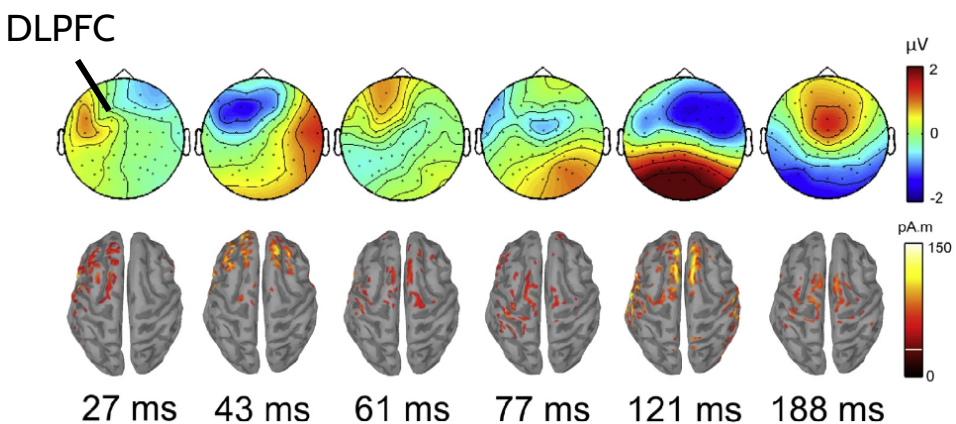
Couplage TMS-EEG

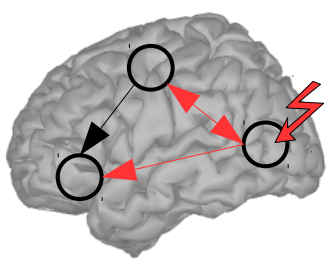


Experimental setup



Local effect

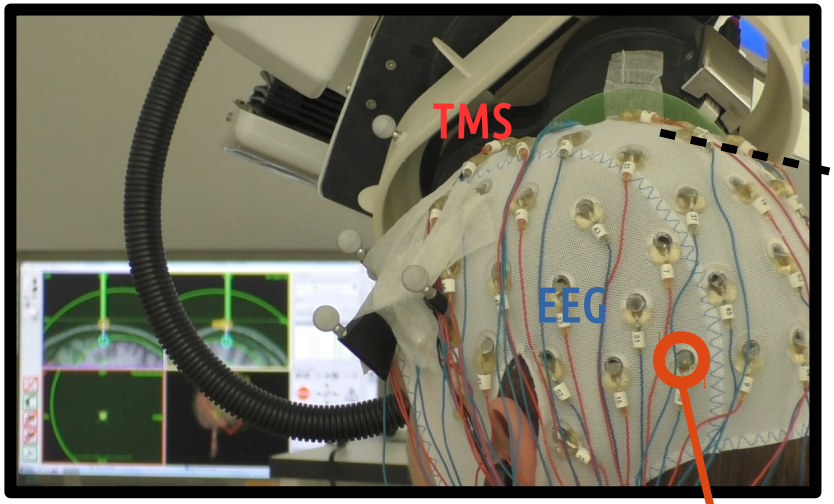




Distributed effect

Chung et al., *Brain Stimulation*, 2015

Aspects techniques - Acquisition



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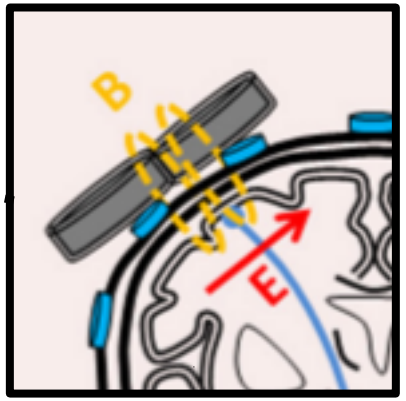


Échauffement !
Amplificateurs !
Artefacts !

- Utilisation d'un matériel **adapté**
- Casques et amplis **compatibles TMS**

(i) Artefact de stimulation
(ii) Artefact de recharge
(iii) Contractions musculaires (scalp)
(iv) Mouvements oculaires
(v) Potentiel évoqué acoustique

(i) Artefact de stimulation

Origine

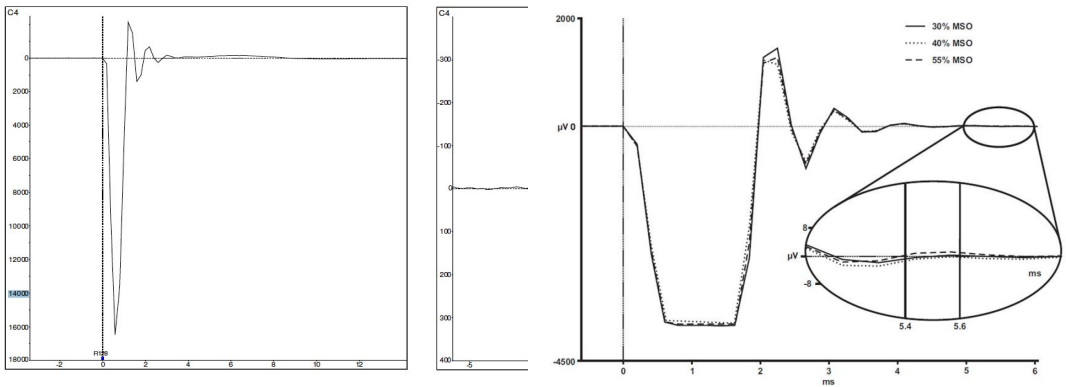
courants induits au sein des électrodes à chaque impulsion (courants de Foulcault)

Amplitude

très grande (de l'ordre de la dizaine de mV)

Durée

- courte (<10ms) mais dépend de l'impédance **des électrodes** (décharge)
- ne dépend pas de l'intensité



- ✔ **Impédances** des électrodes aussi **basses** que possible (< 5 kOhm)
- ✔ **Fréquence** échantillonnage **élevée**
- ✔ Matériel **adapté**
- ✔ Suppression lors du **pré-traitement**

Veniero et al., *Clin. Neurophy.*, 2009

(ii) Artefact de recharge

Origine

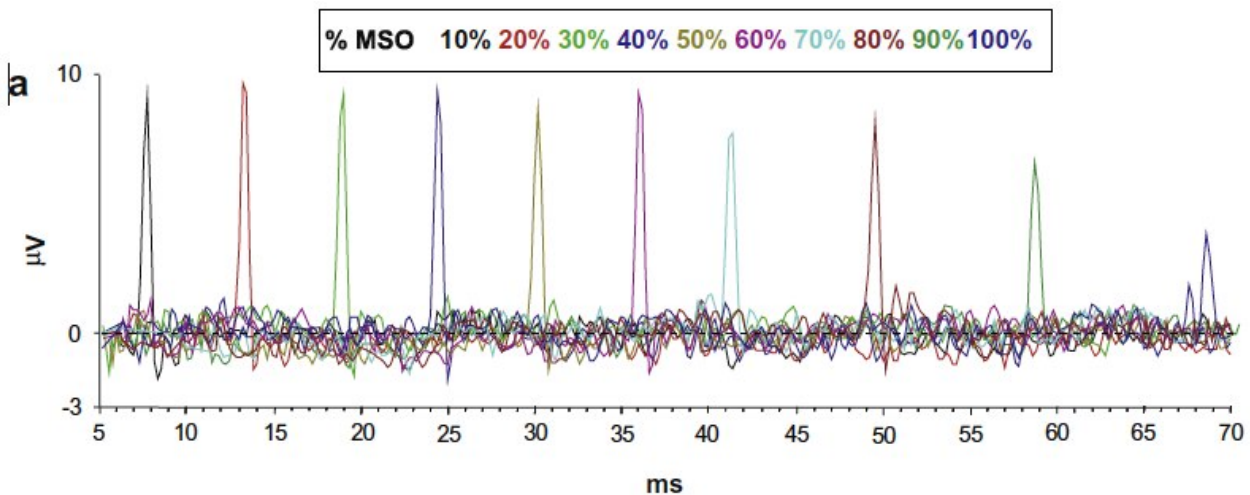
recharge condensateurs du stimulateur

Amplitude

dépend de la configuration / stimulateur

Latence

corrélée positivement avec l'intensité de stimulation



- ✔ **Stimulateur** dépendant !
- ✔ **Blindage** électromagnétique

Veniero et al., *Clin Neurophysiol*, 2009

(iii) Contraction musculaire

Origine

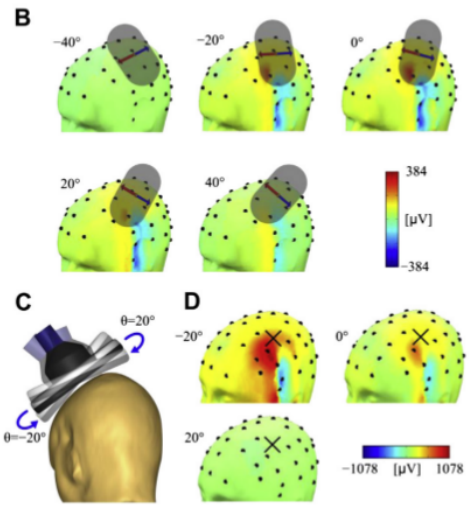
courants induits au niveau des muscles du scalp

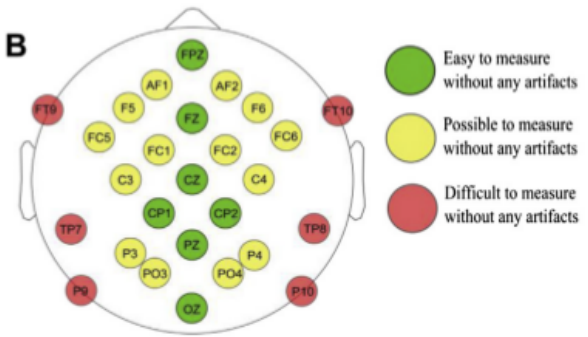
Durée

courte (<20ms) mais dépend de l'impédance **des électrodes**

Amplitude

- grande (de l'ordre de qques mV)
- dépend du site stimulé et de la puissance utilisée





- ✔ Choisir des **paramètres** de stimulation **minimisant** les contractions
- ✔ Suppression lors du **pré-traitement**

Mutanen, *Brain Stim.*, 2013

(iv) Mouvements oculaires

Origine

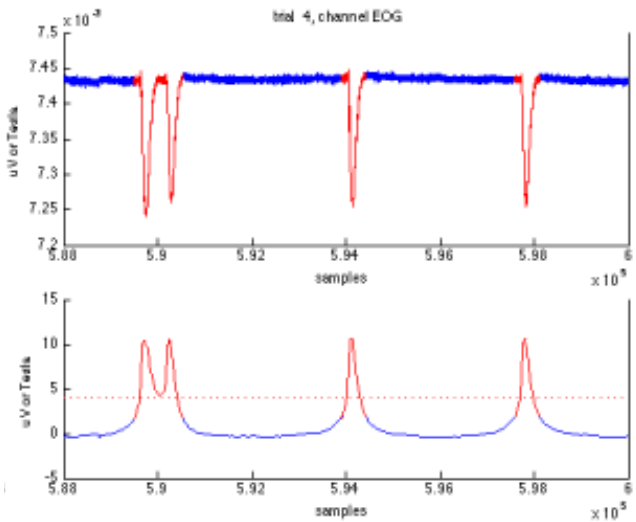
clignements réflexes, mouvements horizontaux

Latence

variable (fixe ou random)

Amplitude

grande (de l'ordre de 100 µV)



- ✔ Croix de **fixation**
- ✔ Suppression lors du **pré-traitement**

D'après Fieldtrip

(v) PE acoustique

Origine

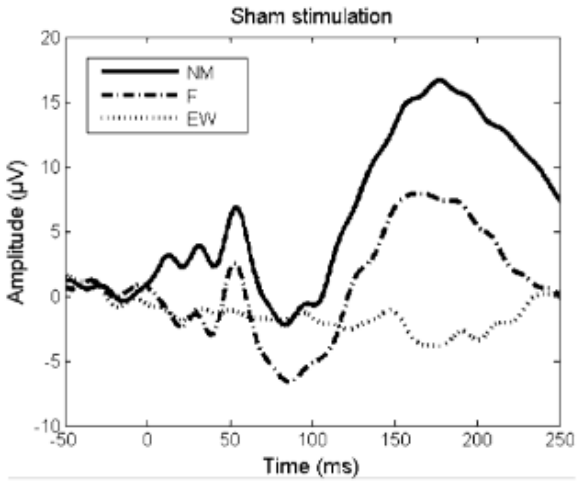
clic produit par les pulses TMS

Latence

100 et 200 ms au niveau des électrodes centrales

Amplitude

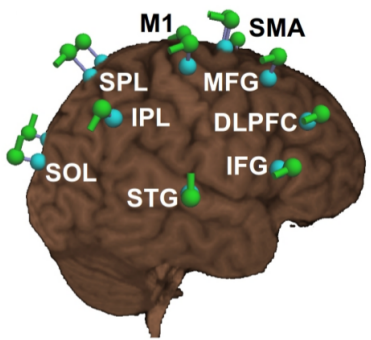
signal neuronal (de l'ordre de qques µV)

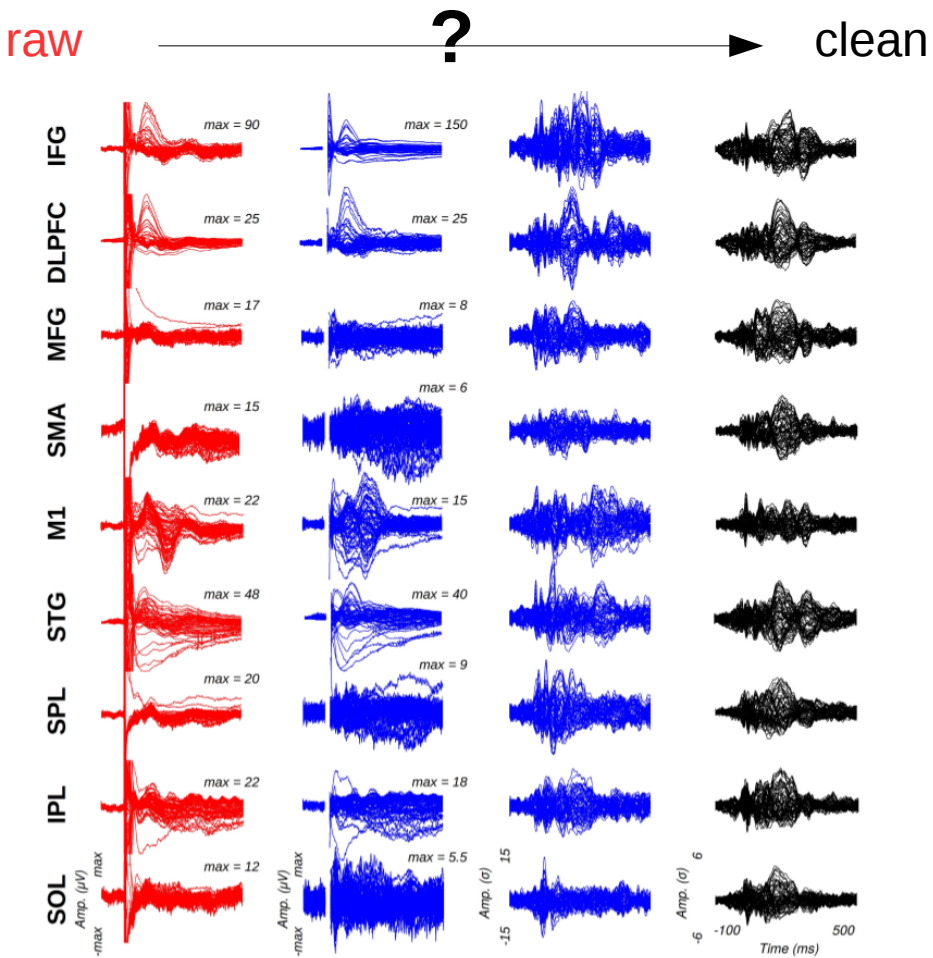


- **Casque audio** (intra) + **bruit blanc**
- Couche de **mousse** entre bobine et casque EEG
- Suppression lors du **pré-traitement**

Braack, *Brain Topo.*, 2013

Aspects techniques – Pré-traitement





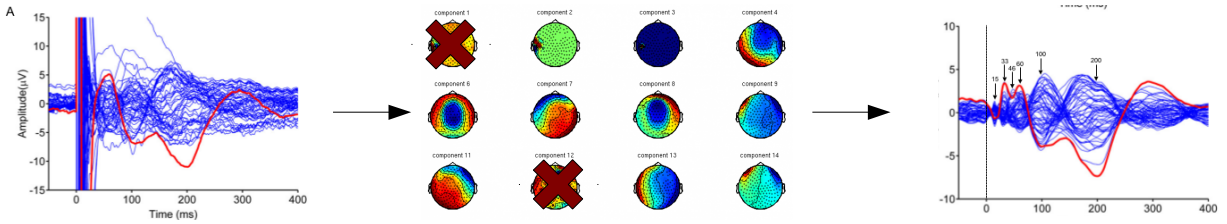
N trials = [80 – 200]
ISI = 2 s minimum + jitter

Harquel et al., *NeuroImage*, 2016

Aspects techniques – Pré-traitement

raw ——— ? ———▶ clean

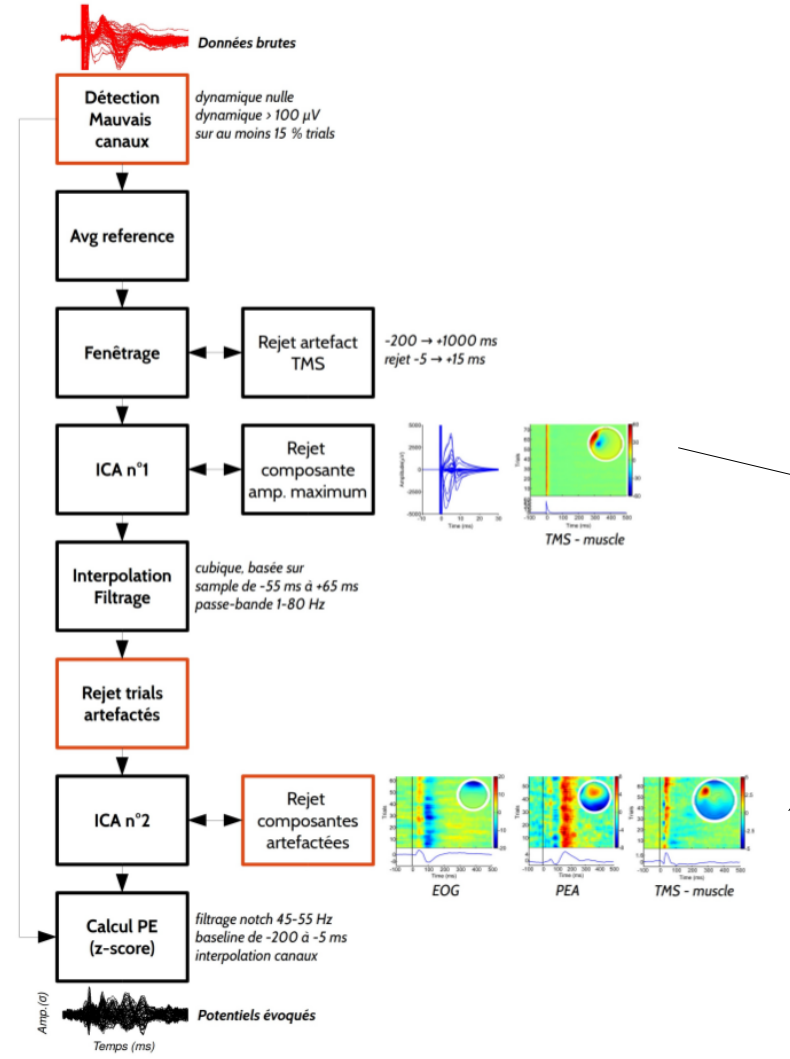
- **Faible SNR → pipelines** de traitement **spécifiques**
  - Plusieurs méthodologies coexistantes
  - Majorité basée sur décomposition signal (ICA, SSP, etc.)



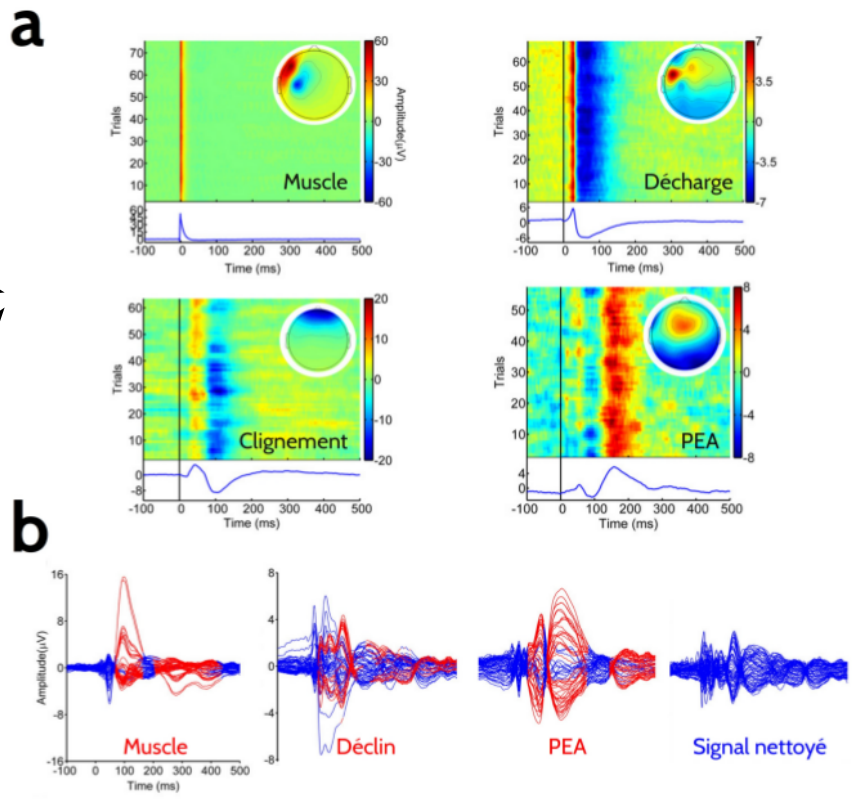
Signal brut — *Composantes indépendantes* — *Signal nettoyé*

- **Variabilité** inter-individuelle et inter-sites
  - Méthodes semi-automatiques
  - Expertise (choix composantes)
  - Peu de méthodes data driven

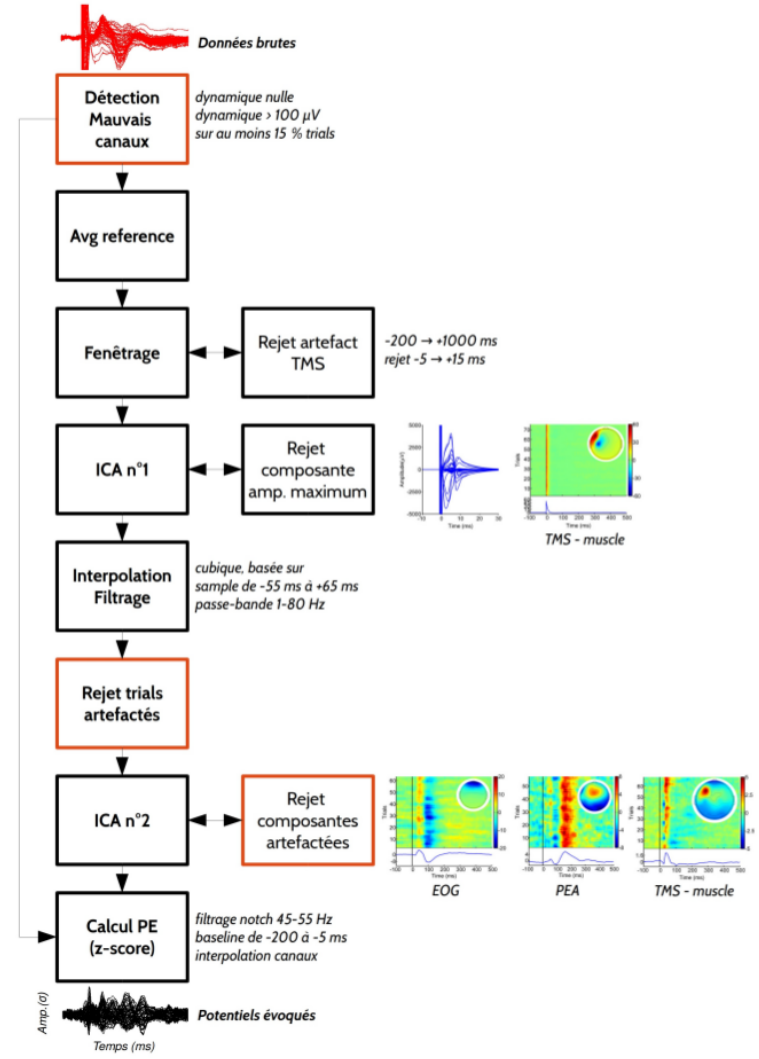
Aspects techniques – Pré-traitement

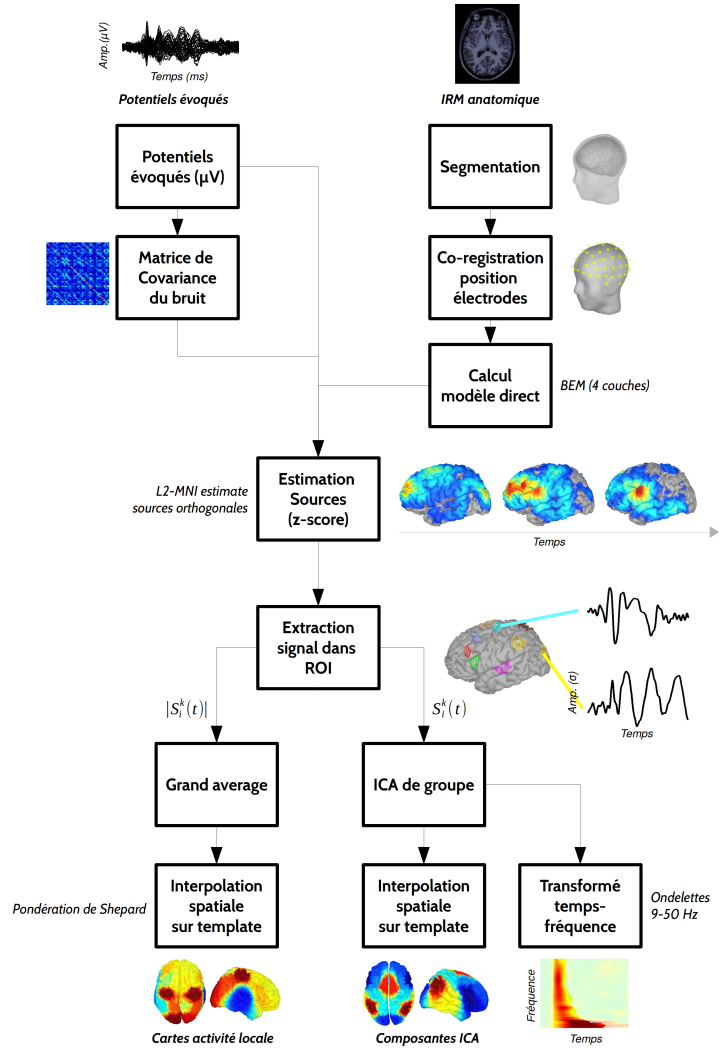


Méthodologie de *Rogasch et al., Neuroimage, 2014*
basée sur 2 rounds d'ICA → cf. ARTIST toolbox (2018)



Aspects techniques – Pré-traitement





Aspects techniques – Solutions existantes

Hardware

- Casques et amplis compatibles TMS :
  - *BrainProducts*
  - *Compumedics Neuroscan*
  - *Nexstim eXimia*

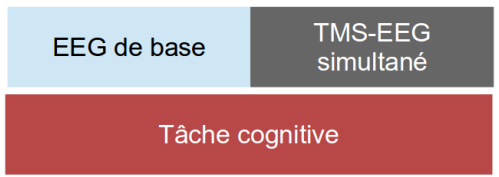
Software

- Toolboxes possédant des fonctions / pipelines dédiés :
  - *Fieldtrip*
  - *EEGlab*
- Toolboxes spécialisées :
  - *TMSEEG toolbox* (matlab) – Farzan et al.
  - *ARTIST* (matlab) – 100% data driven – Rogasch et al.

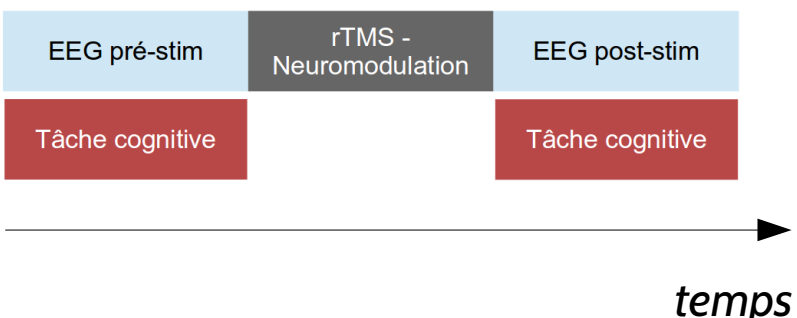
Design expérimental

2 approches :

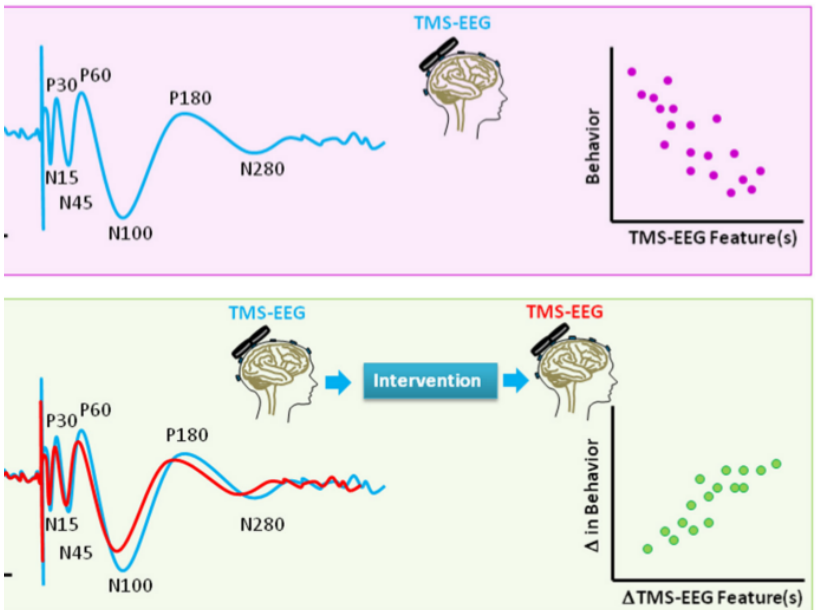
Online



Offline



Corrélats neuronaux des perturbations induites

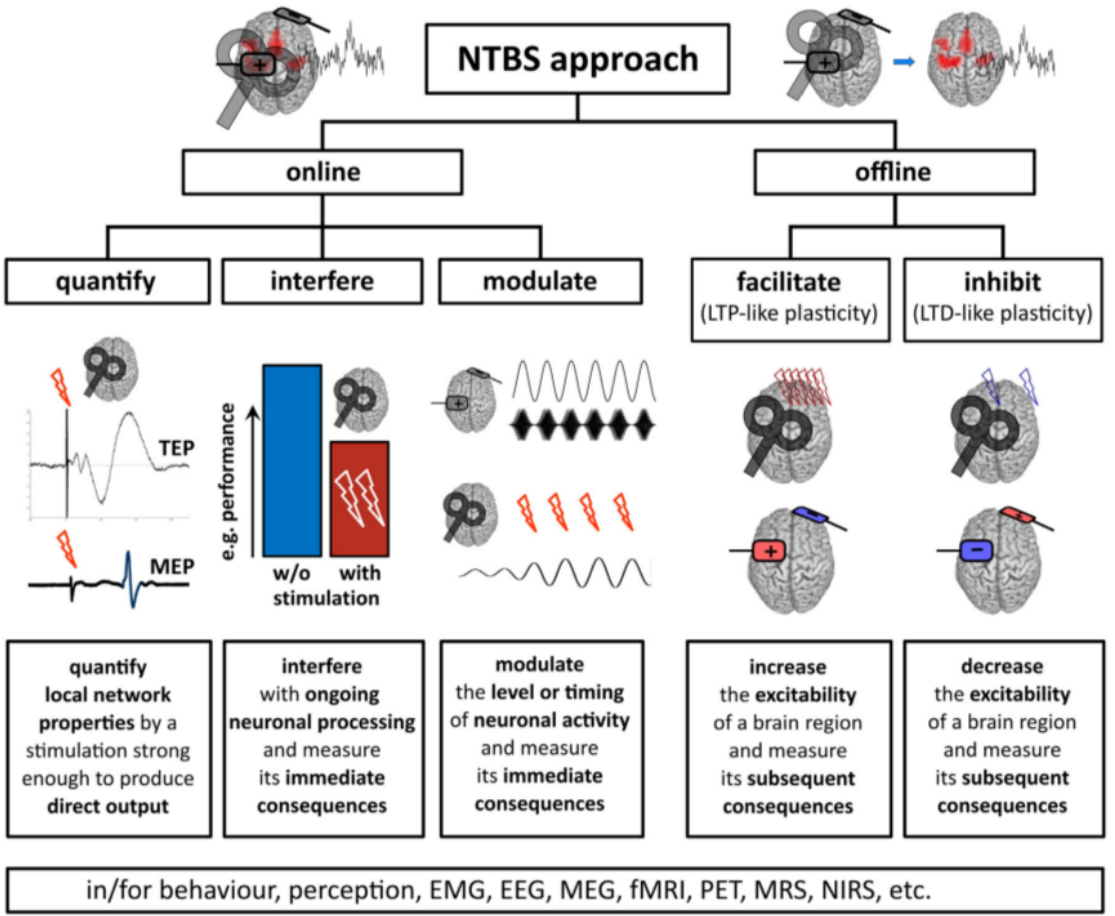


Farzan et al., *Frontiers in neural circuits*, 2016

Applications

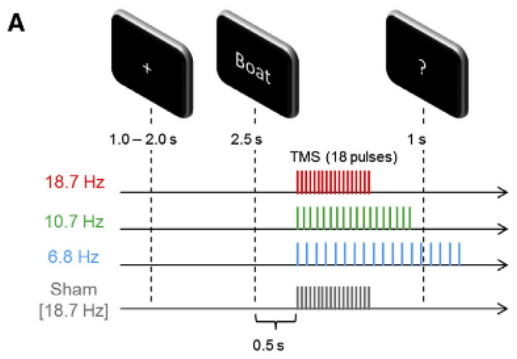
Neurosciences cognitives
- Exploration fonctionnelle
- Étude dynamiques cérébrales

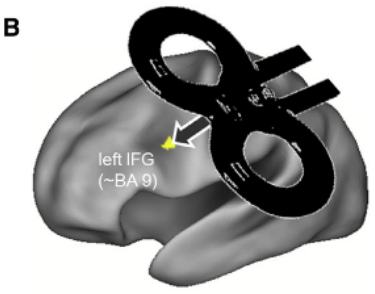
Neurosciences cliniques
- Aide au diagnostic
- Mapping pré-chirurgical

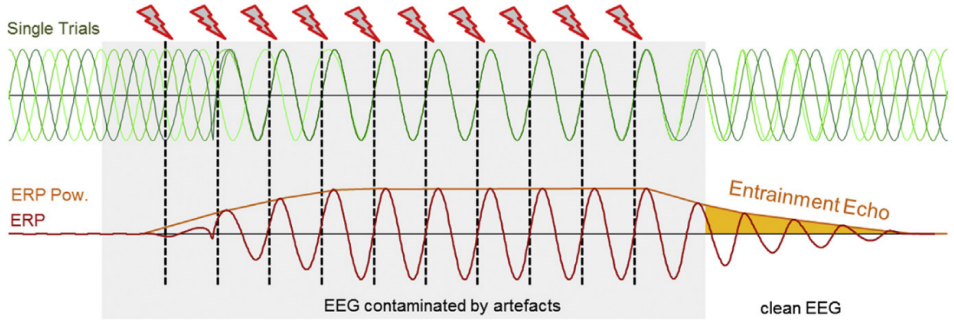


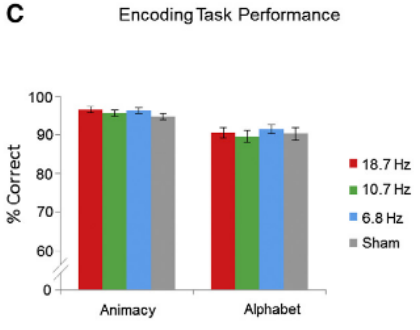
Bergmann et al., *Neuroimage*, 2016

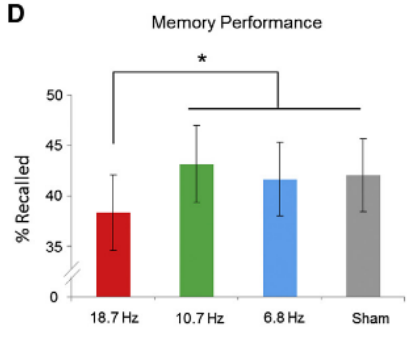
Hanslmayr et al., **Entrainment of Prefrontal Beta Oscillations Induces an Endogenous Echo and Impairs Memory Formation,** *Current Biology*, 2014

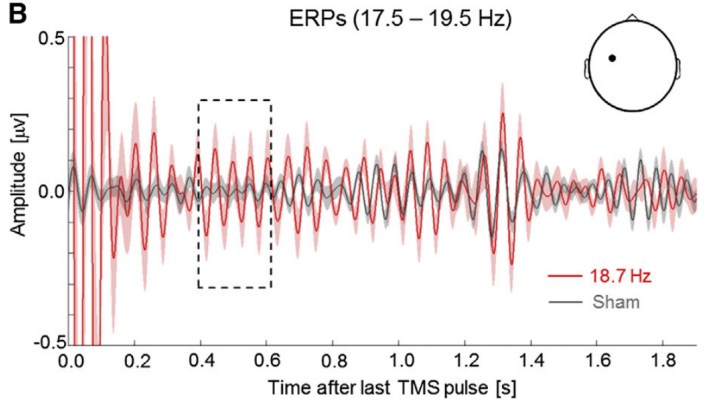












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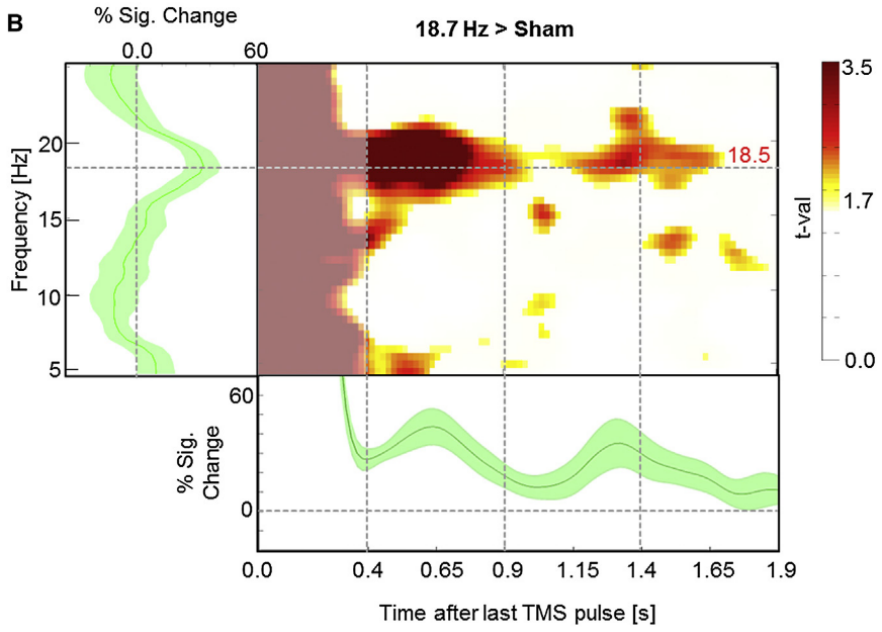
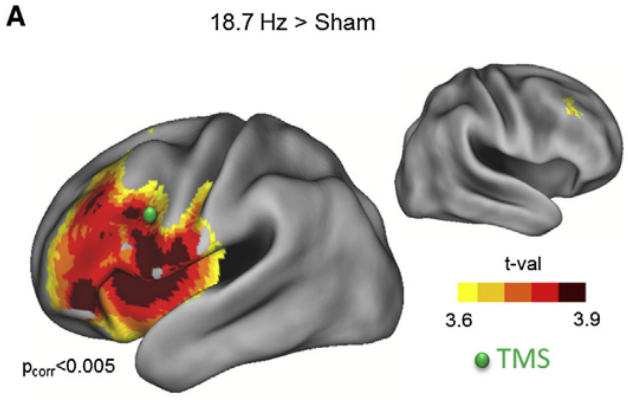
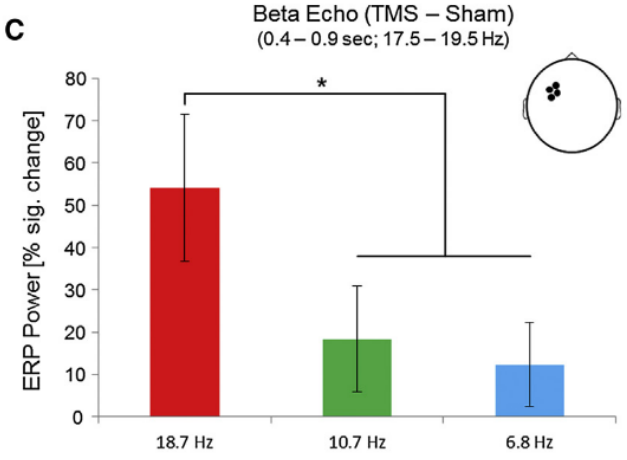
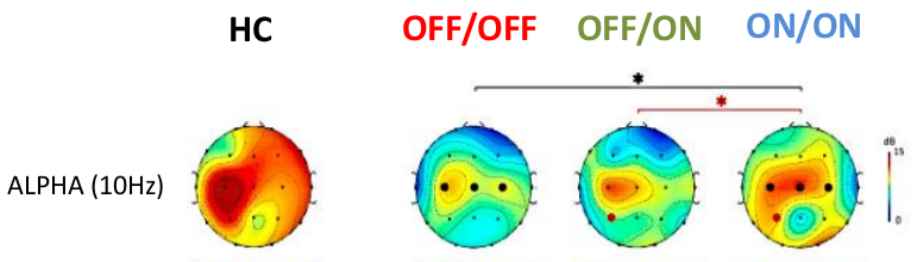




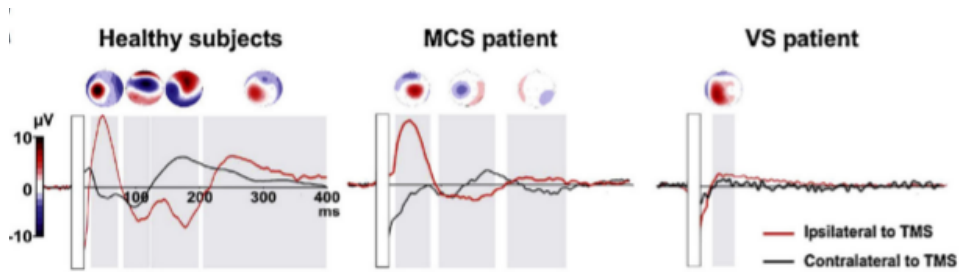


Applications cliniques

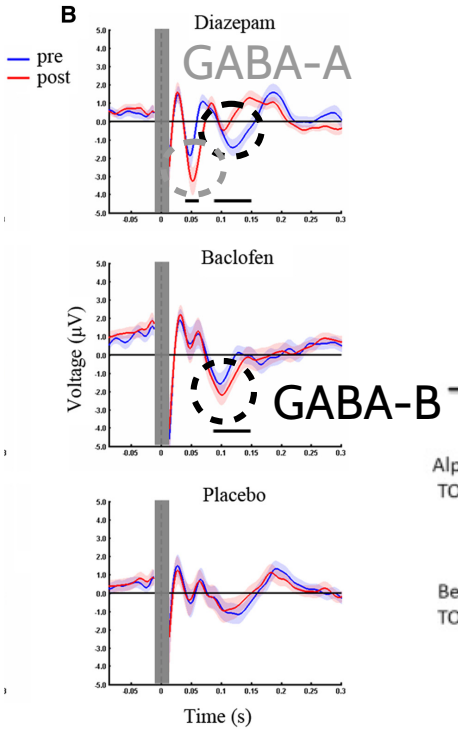
- DBS & Levodopa in PD patients

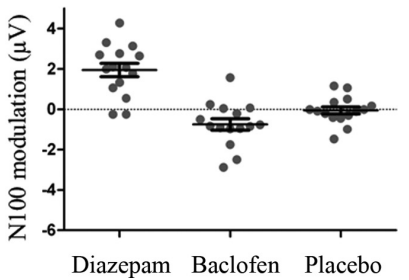


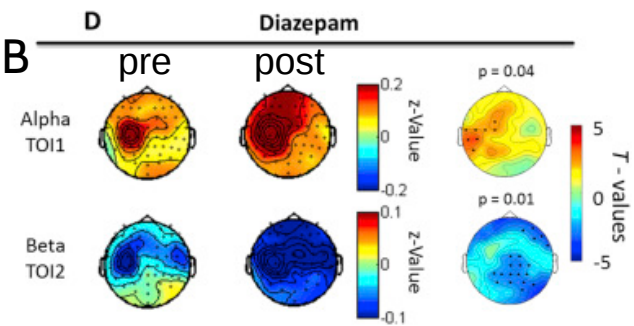
- MCS vs. VS



- Biomarker of drug action and efficacy



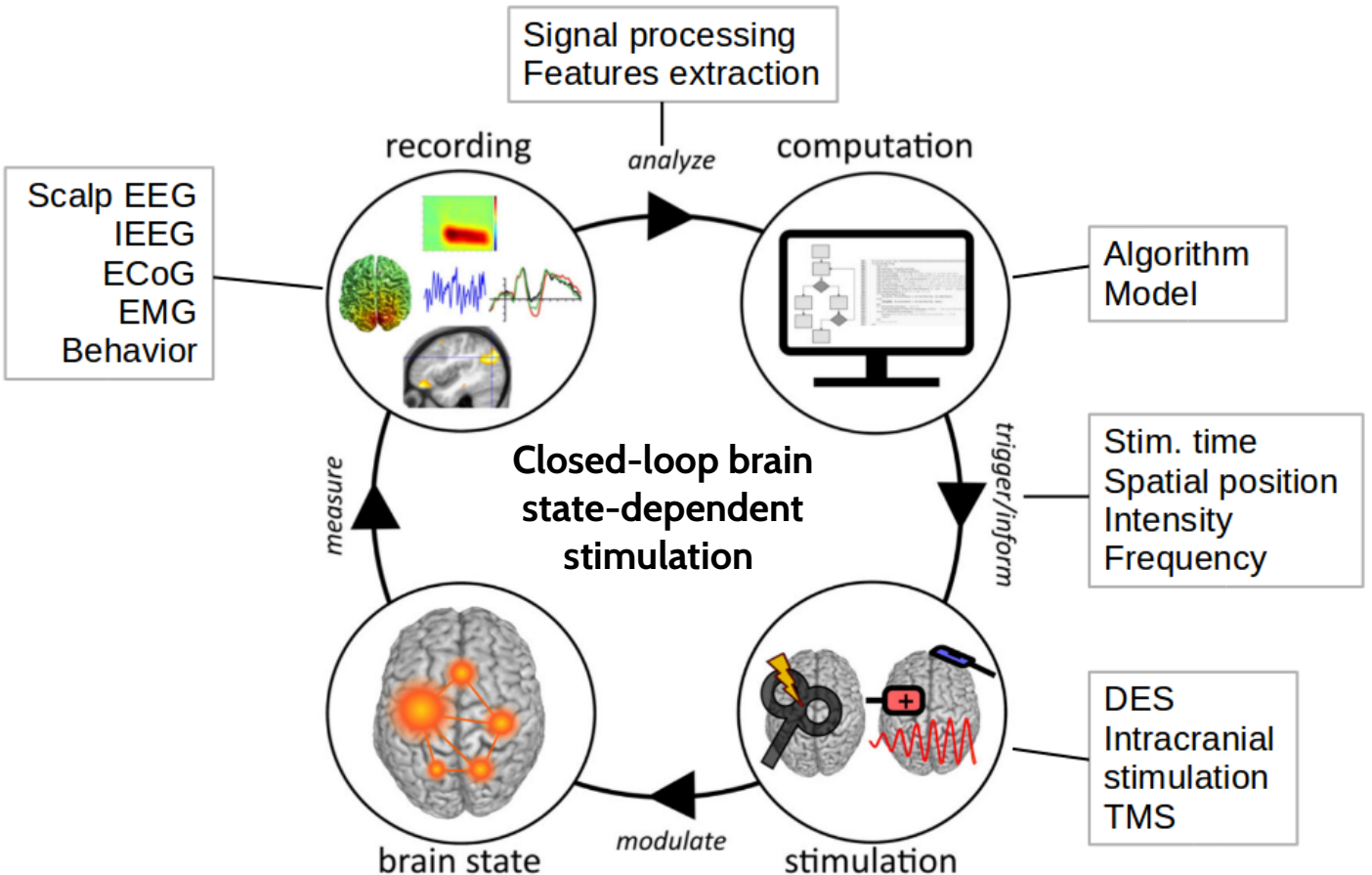




Ragazzoni et al., *Plos One*, 2013 ; Casula et al., *Clinical neurophy.*, 2017

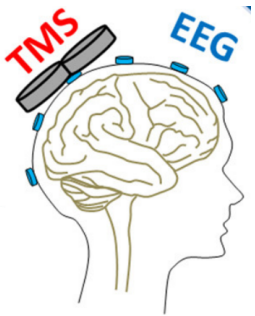
Premoli et al., *J. Neurosi.*, 2014, 2018

« Smart » stimulation



Bergmann et al., *Neuroimage*, 2016 ; Harquel et al., *Neuroimage*, 2017

Merci !



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