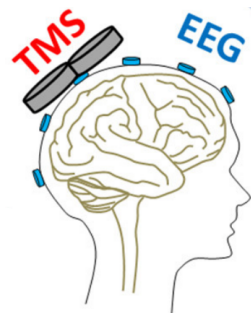


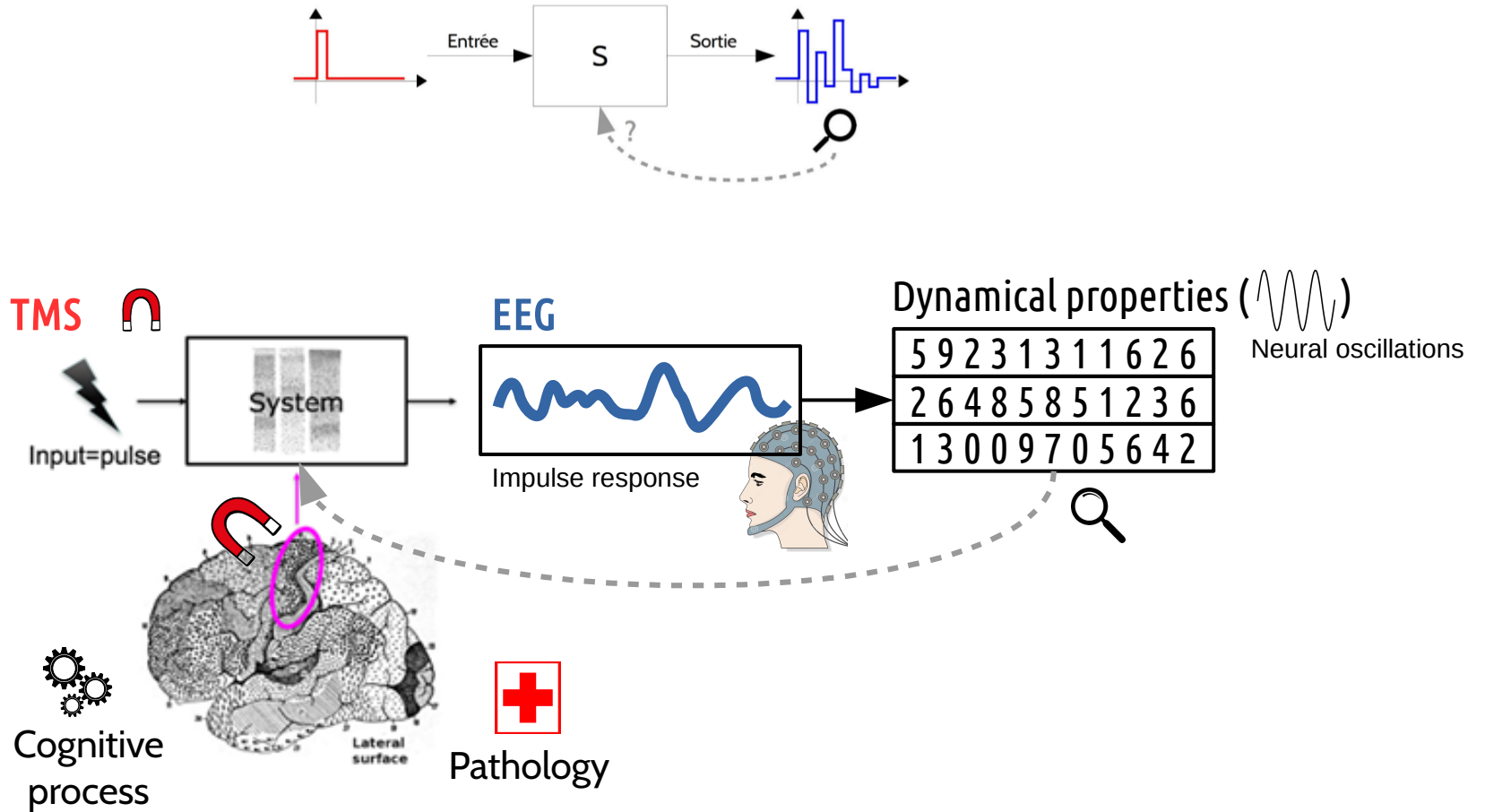


Couplage TMS-EEG : technique et applications

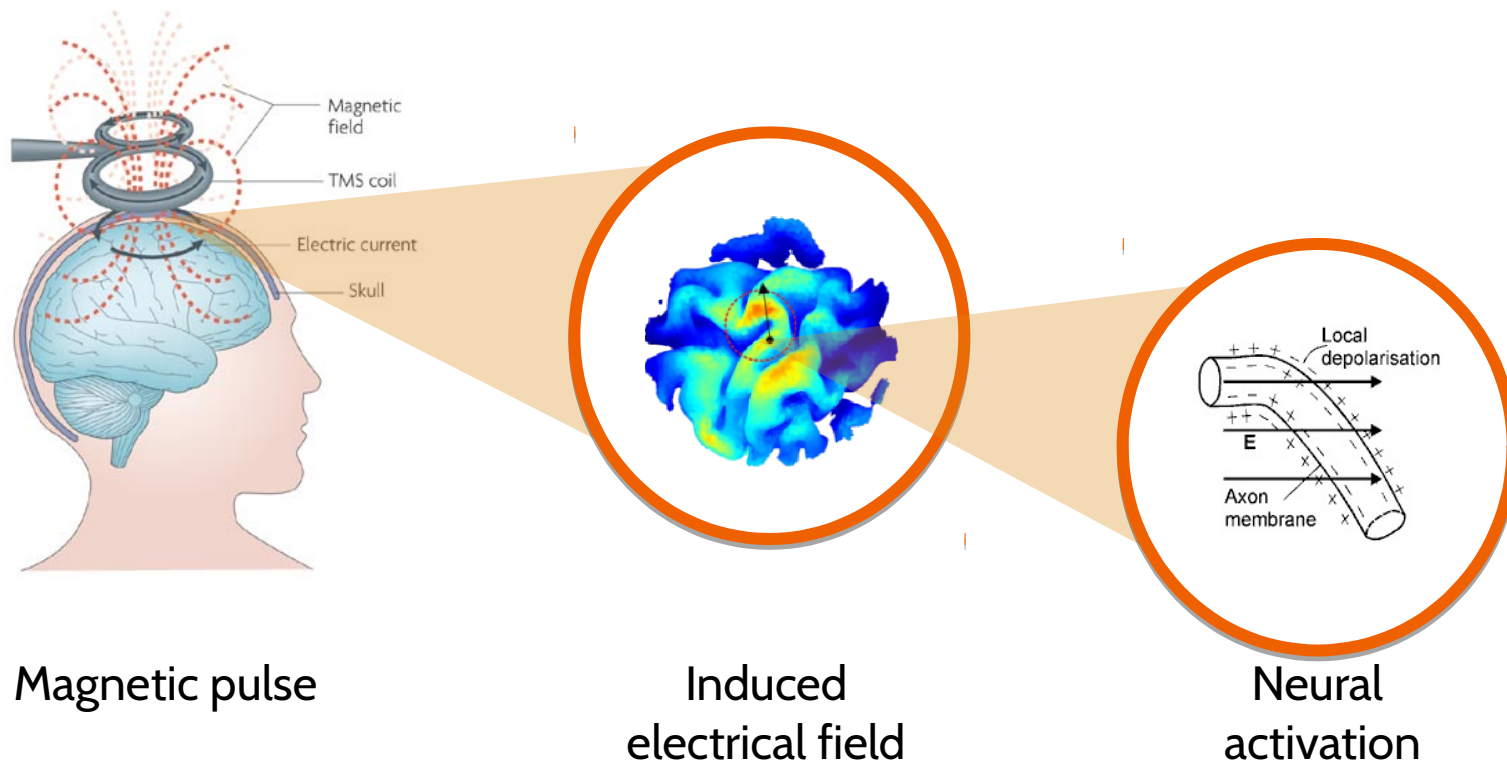


Sylvain Harquel

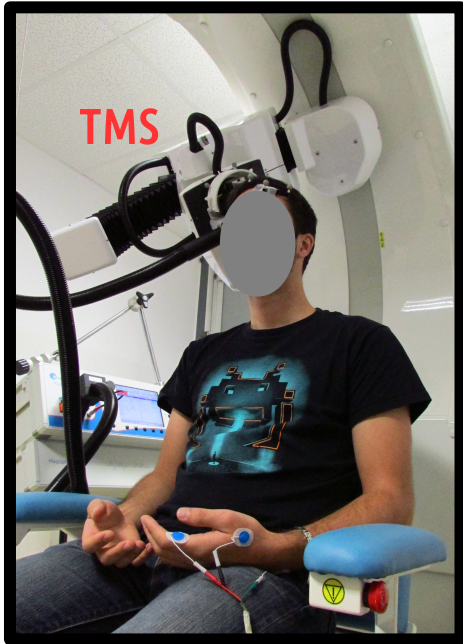
Principe général



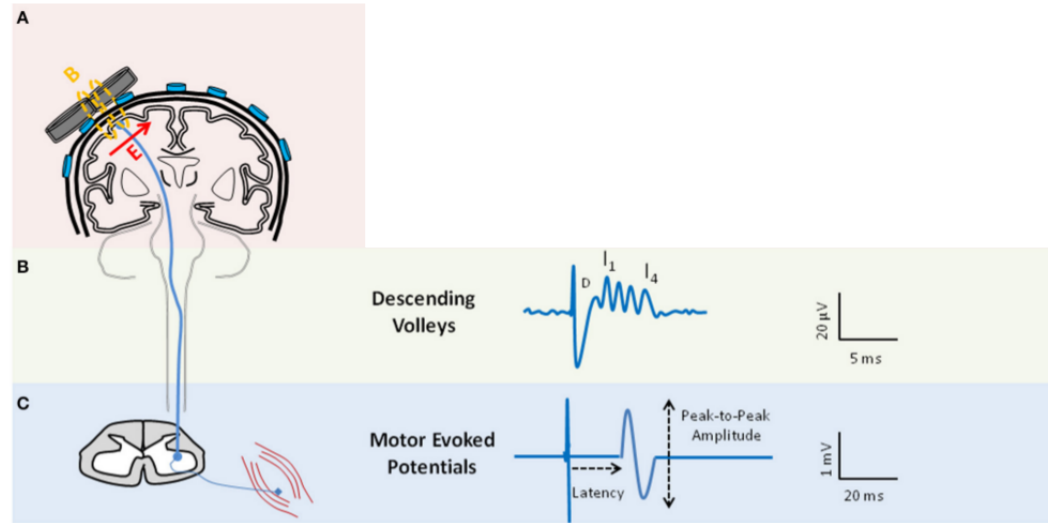
Stimulation Magnétique Transcrânienne



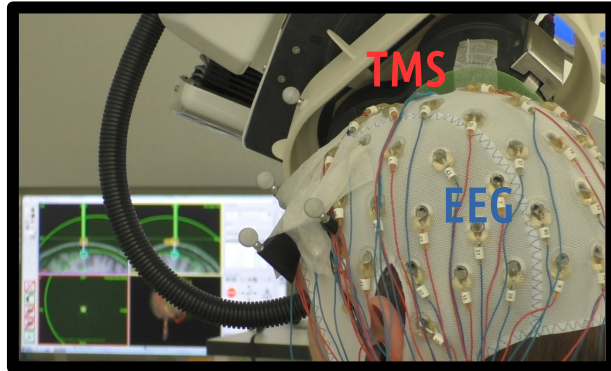
Stimulation Magnétique Transcrânienne



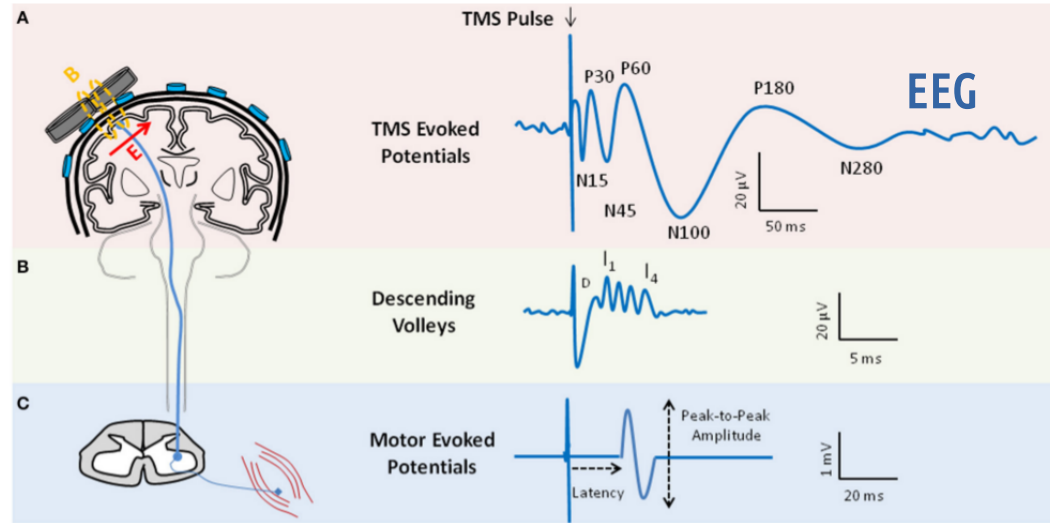
Experimental setup



Couplage TMS-EEG

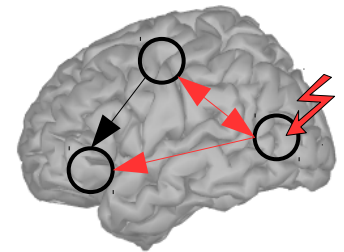
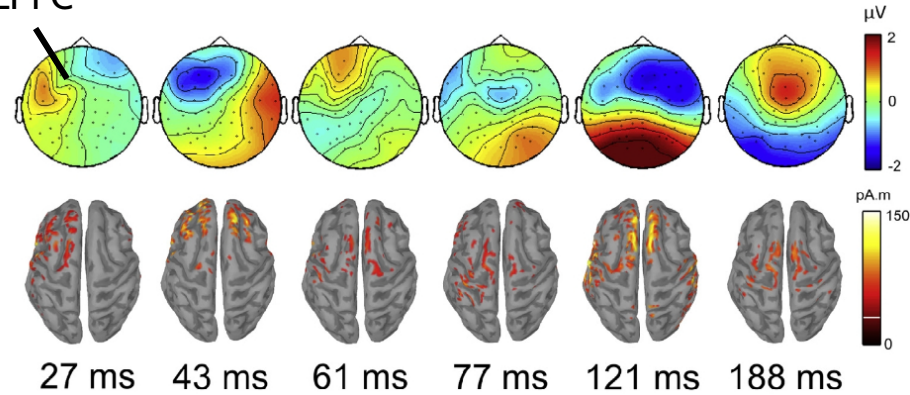


Experimental setup



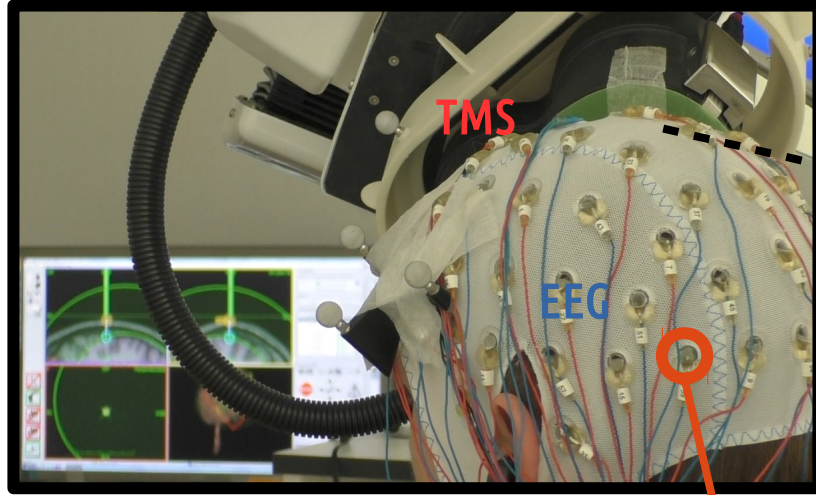
Local effect

DLPFC

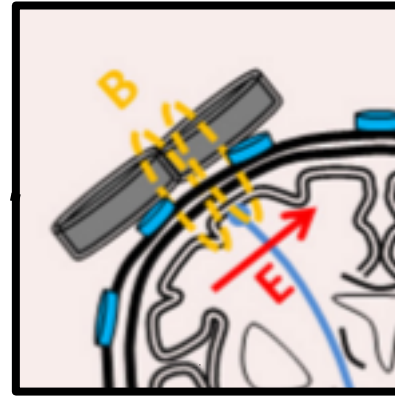


Distributed effect

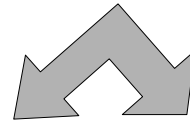
Aspects techniques - Acquisition



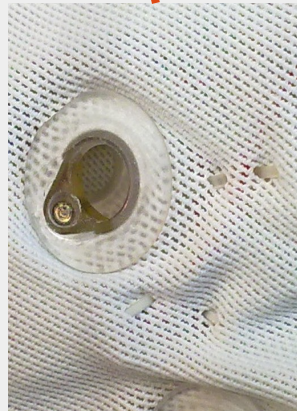
!!!



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

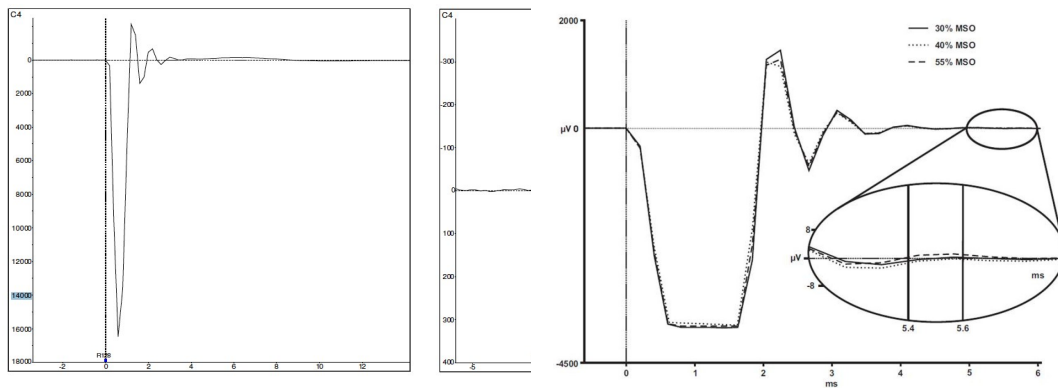
courants induits au sein des électrodes à chaque impulsion (courants de Foucault)

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**

(ii) Artefact de recharge

Origine

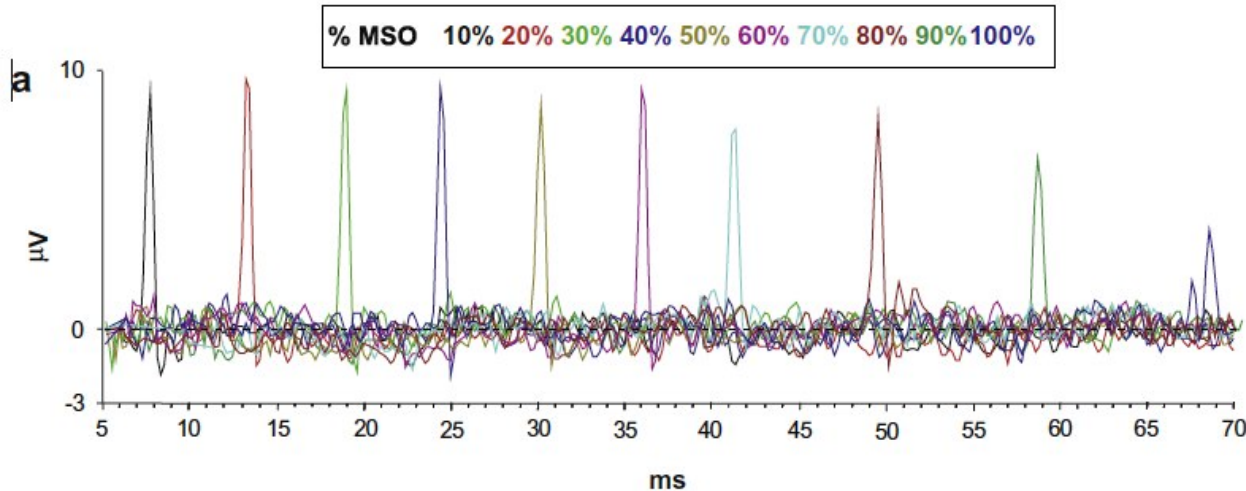
recharge condensateurs du stimulateur

Amplitude

dépend de la configuration / stimulateur

Latence

corrélée positivement avec l'intensité de stimulation



- ✓ **Stimulateur dépendant !**
- ✓ **Blindage électromagnétique**

(iii) Contraction musculaire

Origine

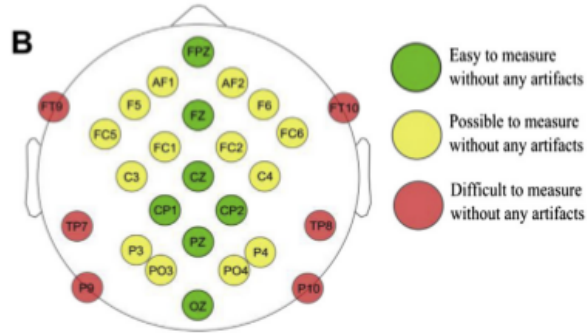
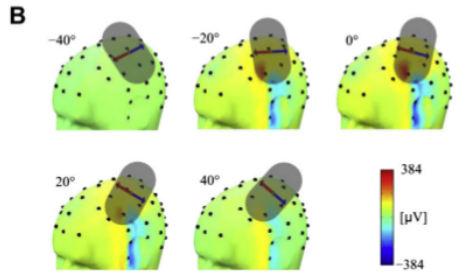
courants induits au niveau des muscles du scalp

Durée

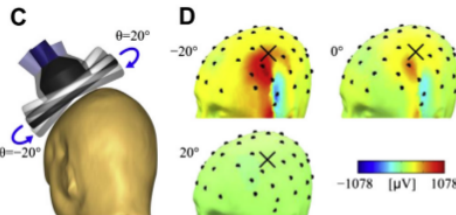
courte (<20ms) mais dépend de l'impédance **des électrodes**

Amplitude

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



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



(iv) Mouvements oculaires

Origine

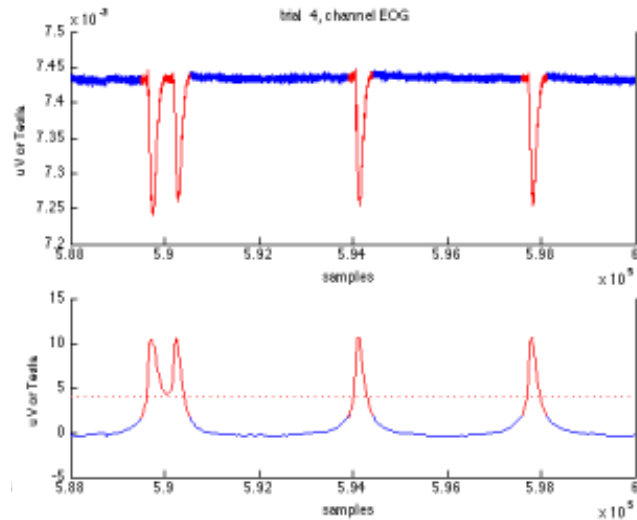
clignements réflexes, mouvements horizontaux

Latence

variable (fixe ou random)

Amplitude

grande (de l'ordre de 100 μV)



- ✓ Croix de fixation
- ✓ Suppression lors du pré-traitement

Origine

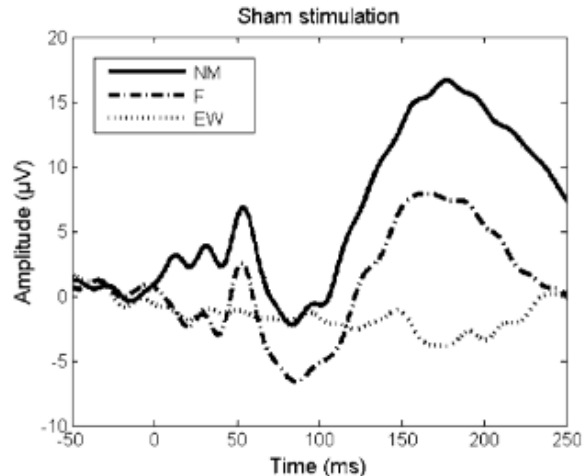
clic produit par les pulses TMS

Latence

100 et 200 ms au niveau des électrodes centrales

Amplitude

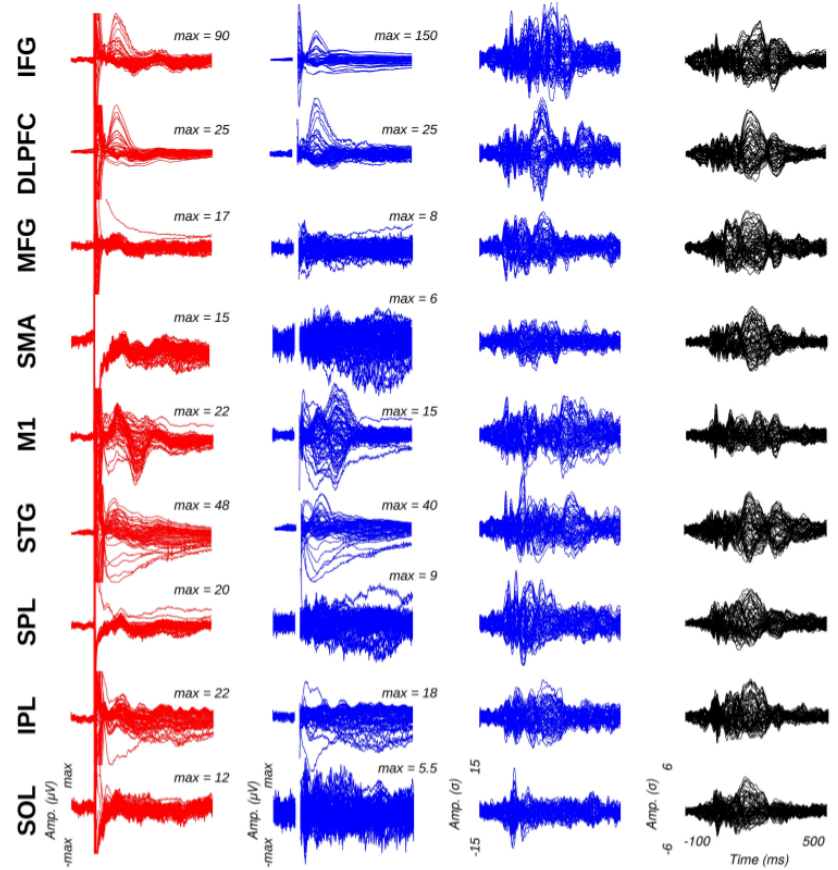
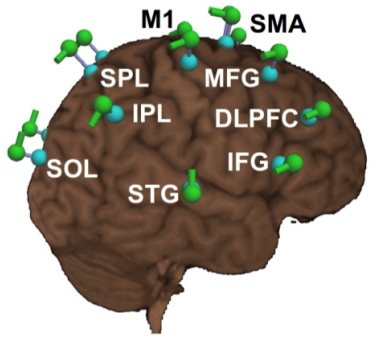
signal neuronal (de l'ordre de qqes μV)



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

Aspects techniques – Pré-traitement

raw ? clean



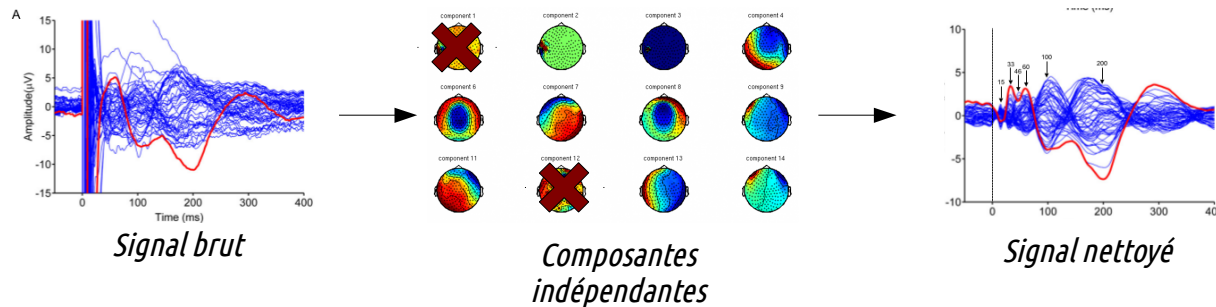
N trials = [80 - 200]
ISI = 2 s minimum + jitter

Aspects techniques – Pré-traitement

raw $\xrightarrow{\quad ? \quad}$ clean

- **Faible SNR** \rightarrow pipelines de traitement spécifiques

- Plusieurs méthodologies coexistantes
- Majorité basée sur décomposition signal (ICA, SSP, etc.)

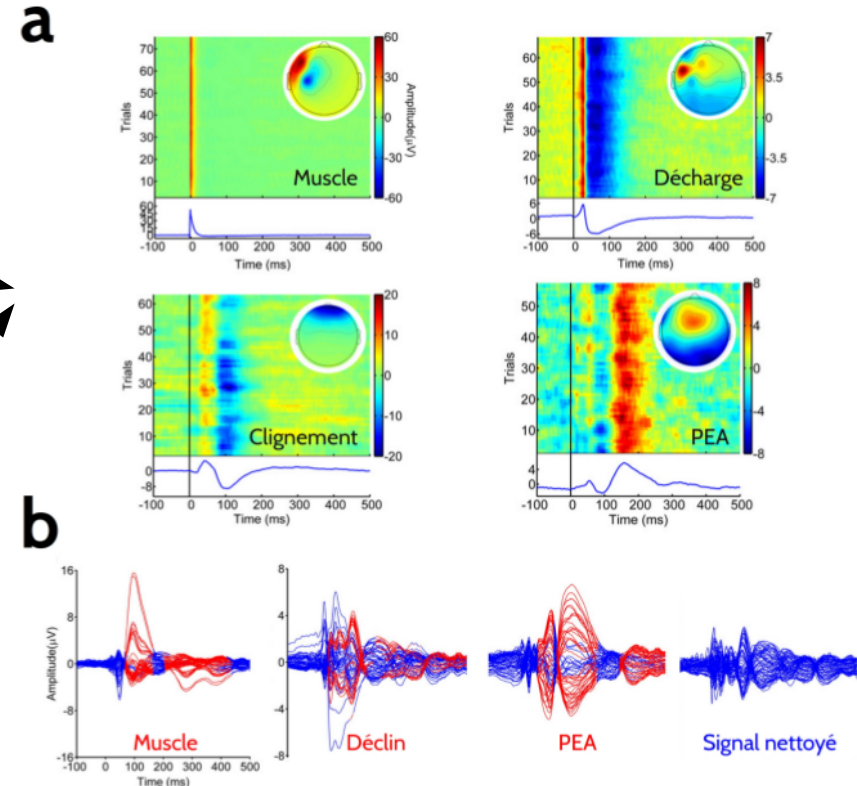
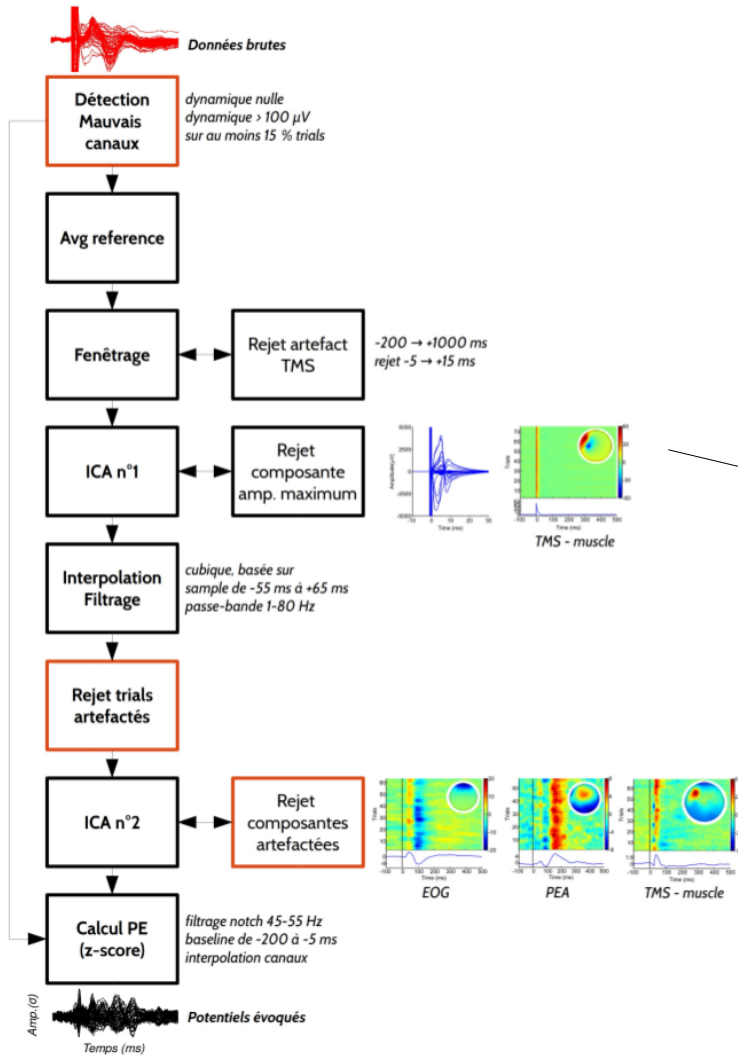


- **Variabilité** inter-individuelle et inter-sites

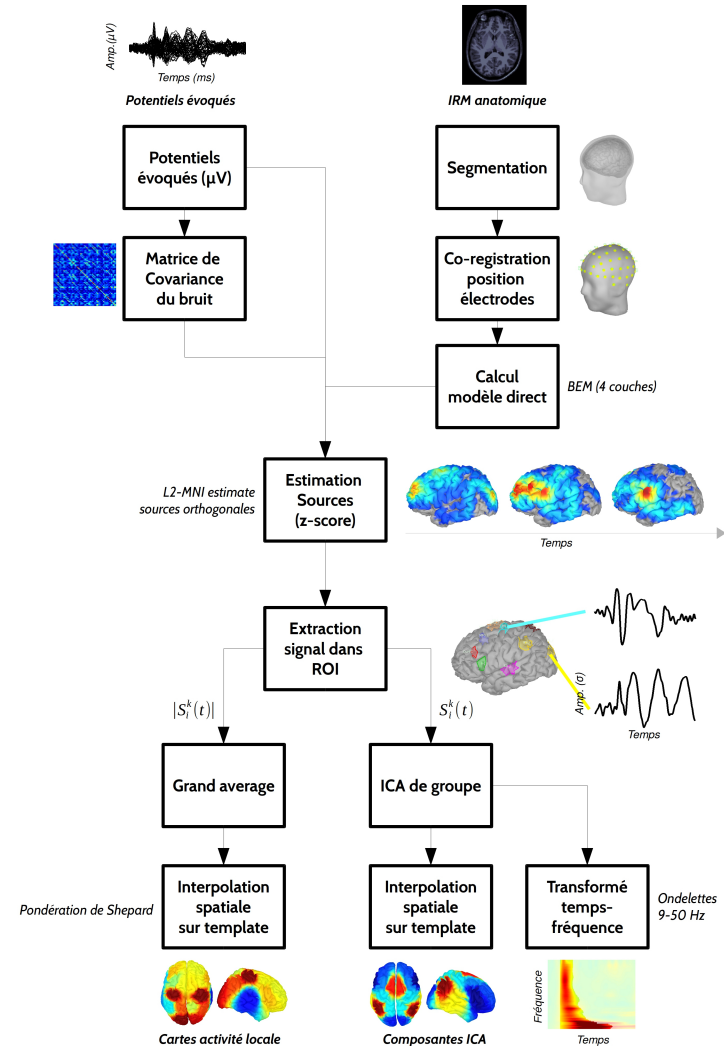
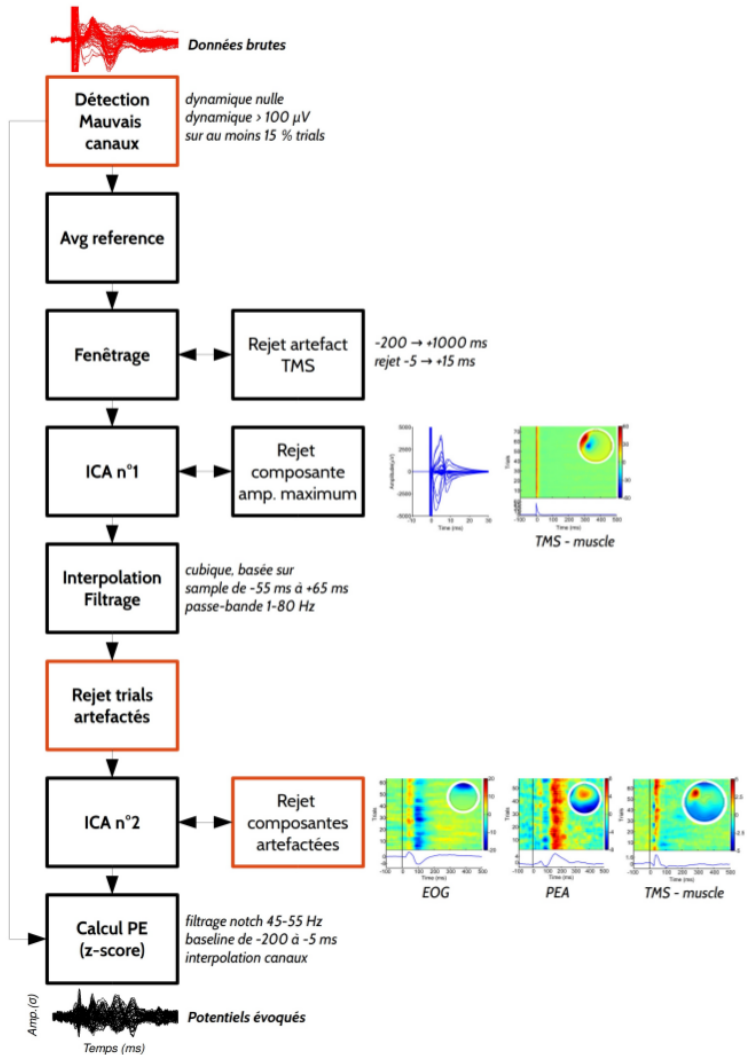
- Méthodes semi-automatiques
- Expertise (choix composantes)
- Peu de méthodes data driven

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



Hardware

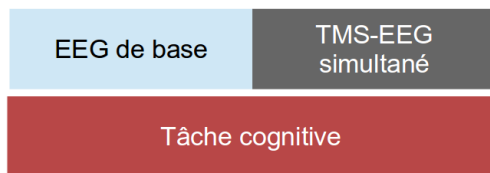
- Casques et amplis compatibles TMS :
 - ✓ *BrainProducts*
 - ✓ *Compumedics Neuroscan*
 - ✓ *Nexstim eXimia*

Software

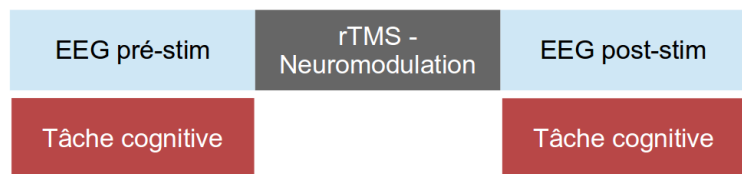
- Toolboxes possédant des fonctions / pipelines dédiés :
 - ✓ *Fieldtrip*
 - ✓ *EEGLab*
- Toolboxes spécialisées :
 - ✓ *TMSEEG toolbox* (matlab) – Farzan et al.
 - ✓ *ARTIST* (matlab) – 100% data driven – Rogasch et al.

2 approches :

Online

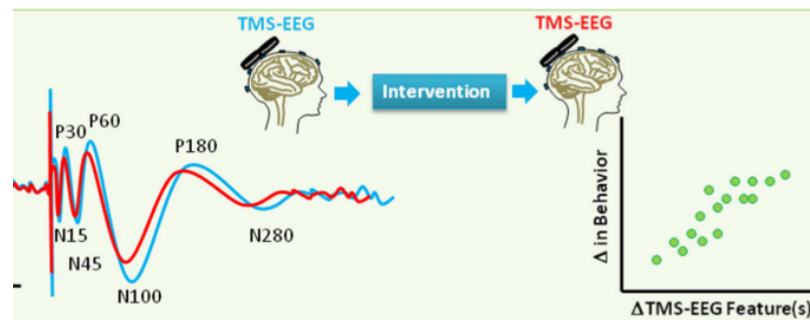
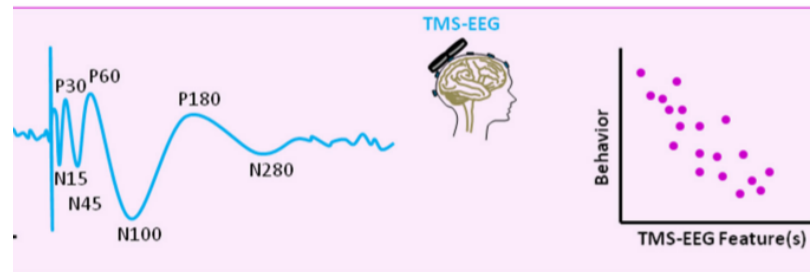


Offline

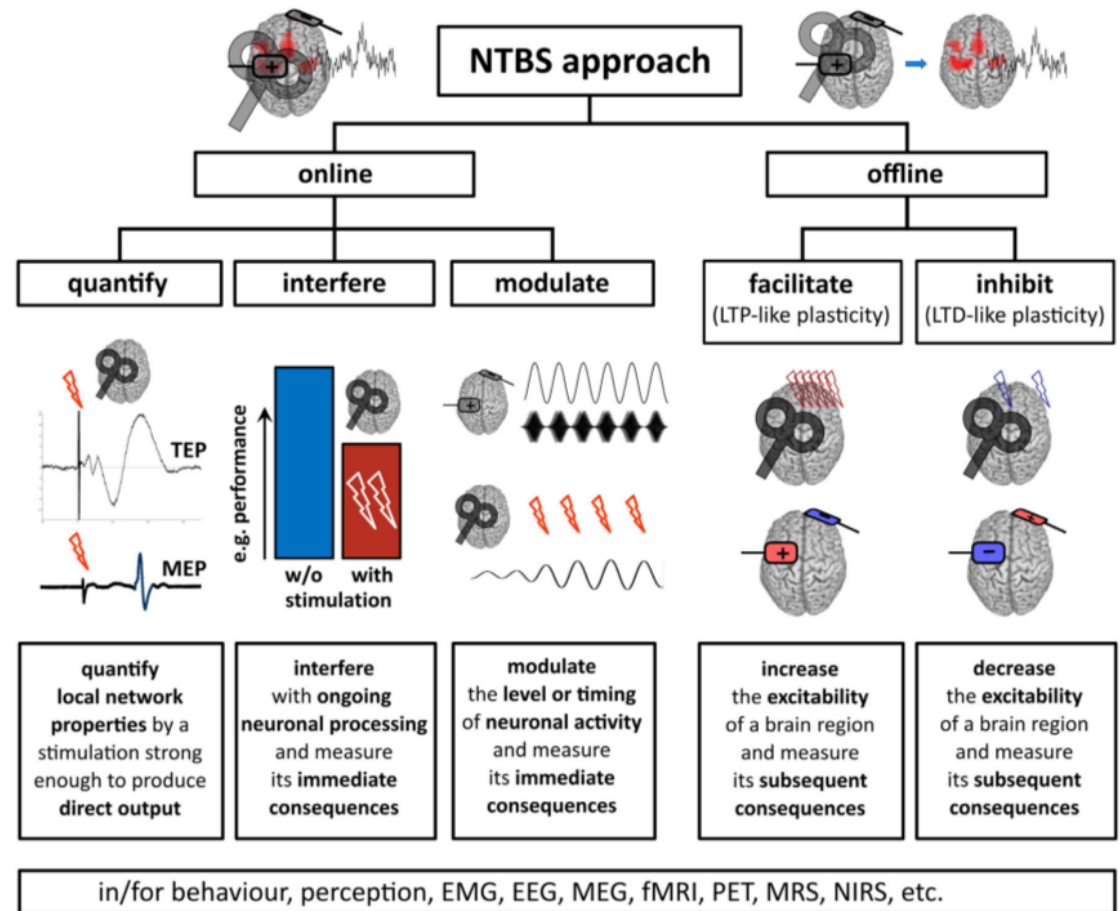


temps

Corrélat neuronal des perturbations induites



Applications



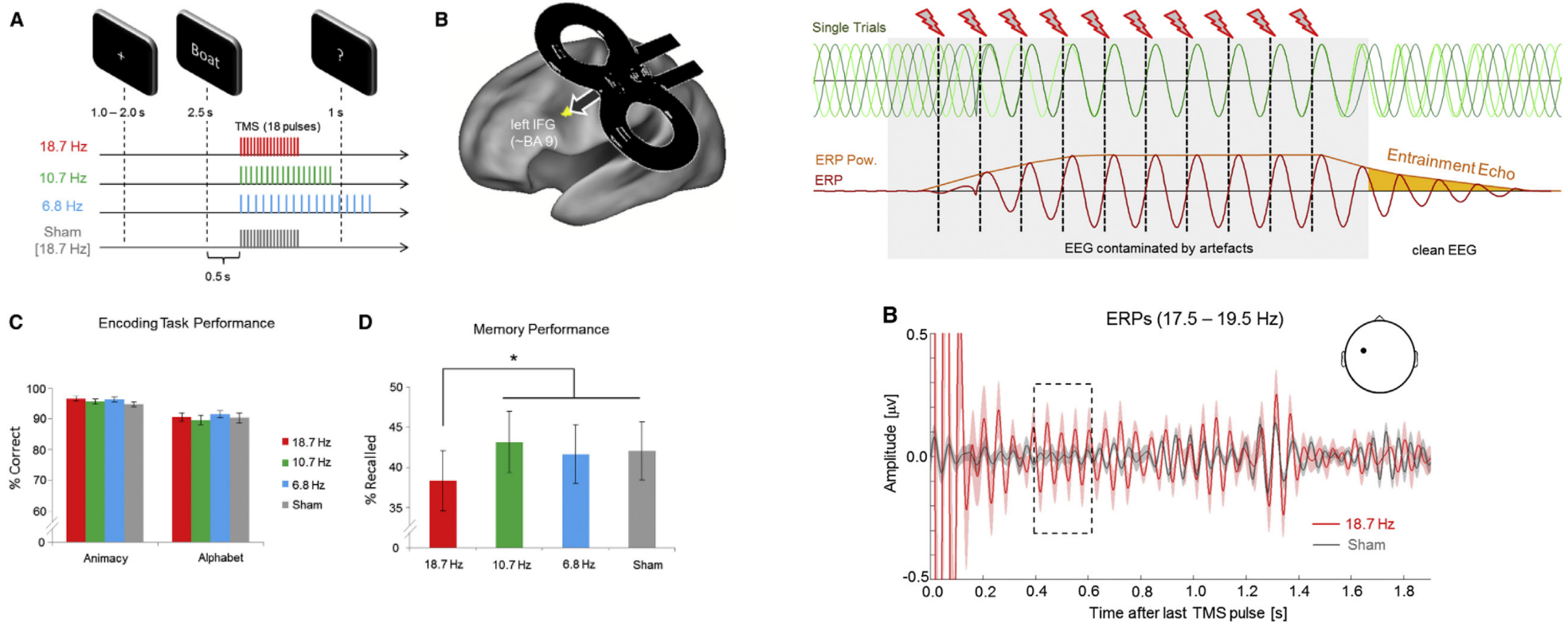
Neurosciences cognitives

- Exploration fonctionnelle
- Étude dynamiques cérébrales

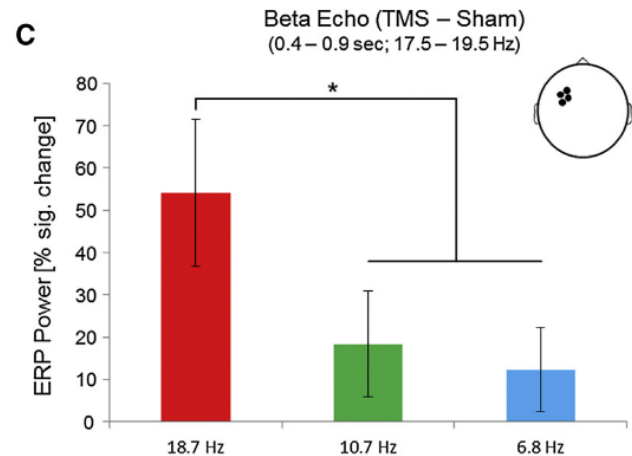
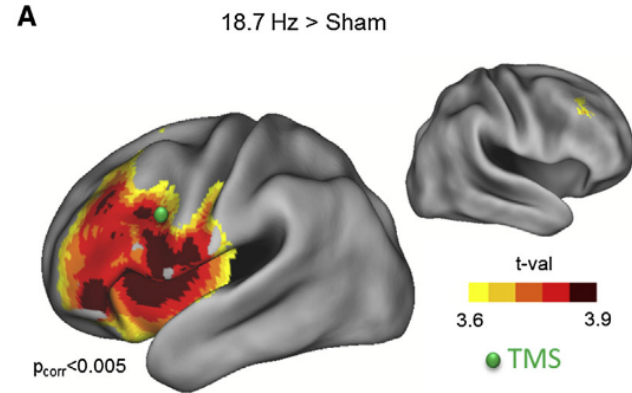
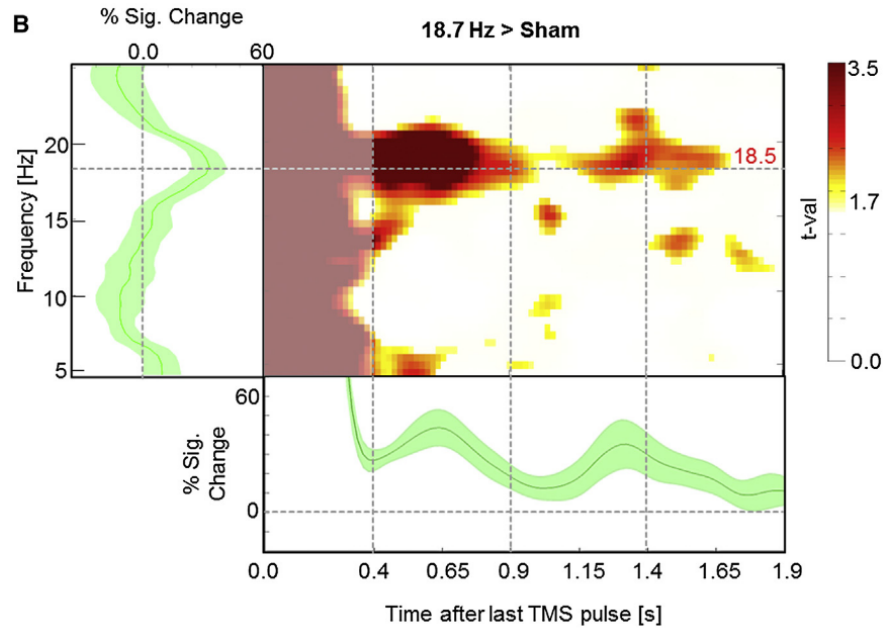
Neurosciences cliniques

- Aide au diagnostic
- Mapping pré-chirurgical

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

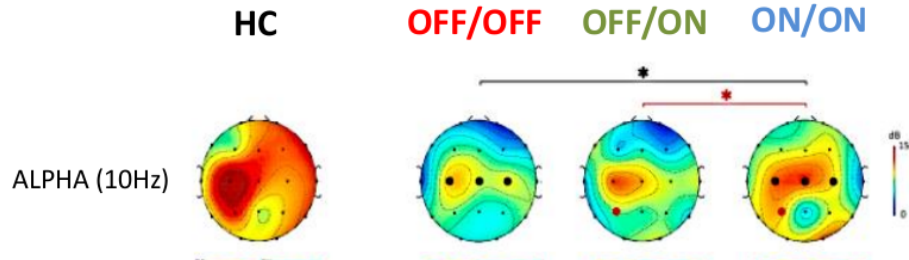


Hanslmayr et al., Entrainment of Prefrontal Beta Oscillations Induces an Endogenous Echo and Impairs Memory Formation, *Current Biology*, 2014

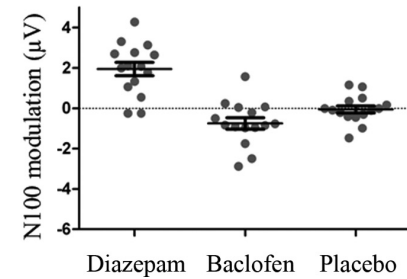
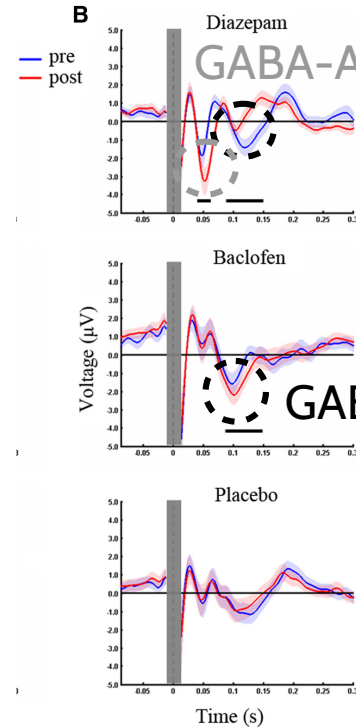


Applications cliniques

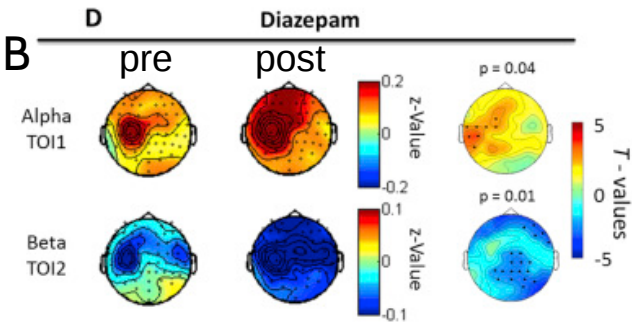
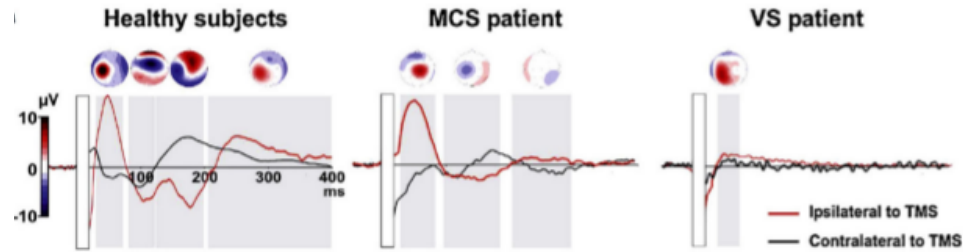
✓ DBS & Levodopa in PD patients



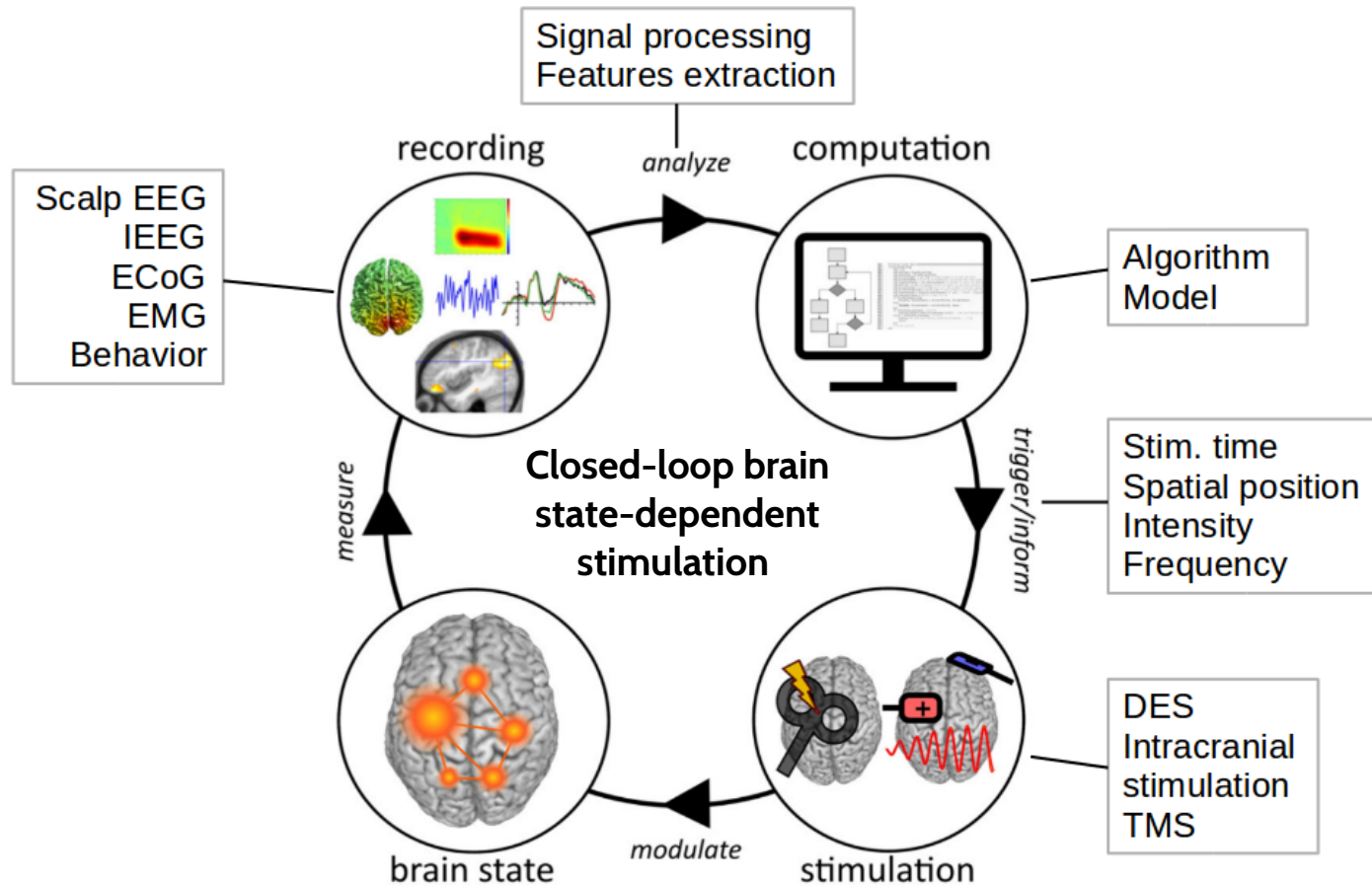
✓ Biomarker of drug action and efficacy



✓ MCS vs. VS



« Smart » stimulation





Merci !

