Transition veille-sommeil: ni éveil, ni sommeil

Mélanie Strauss, MD, PhD

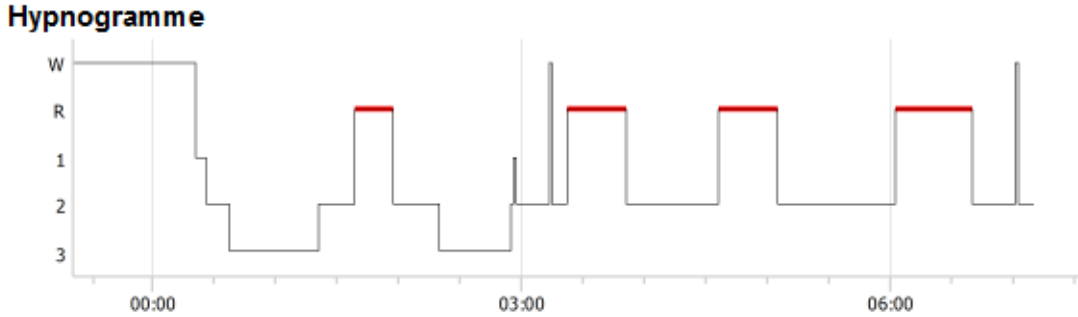
Service de neurologie

Unité Fonctionnelle du Sommeil

Hôpital Universitaire de Bruxelles, Erasme,

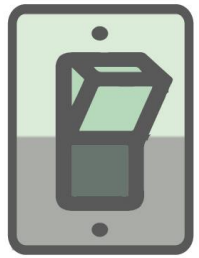
Bruxelles, Belgique

Introduction : de l’éveil au sommeil



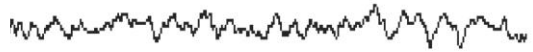
Eveil

Réactivité à l’environnement



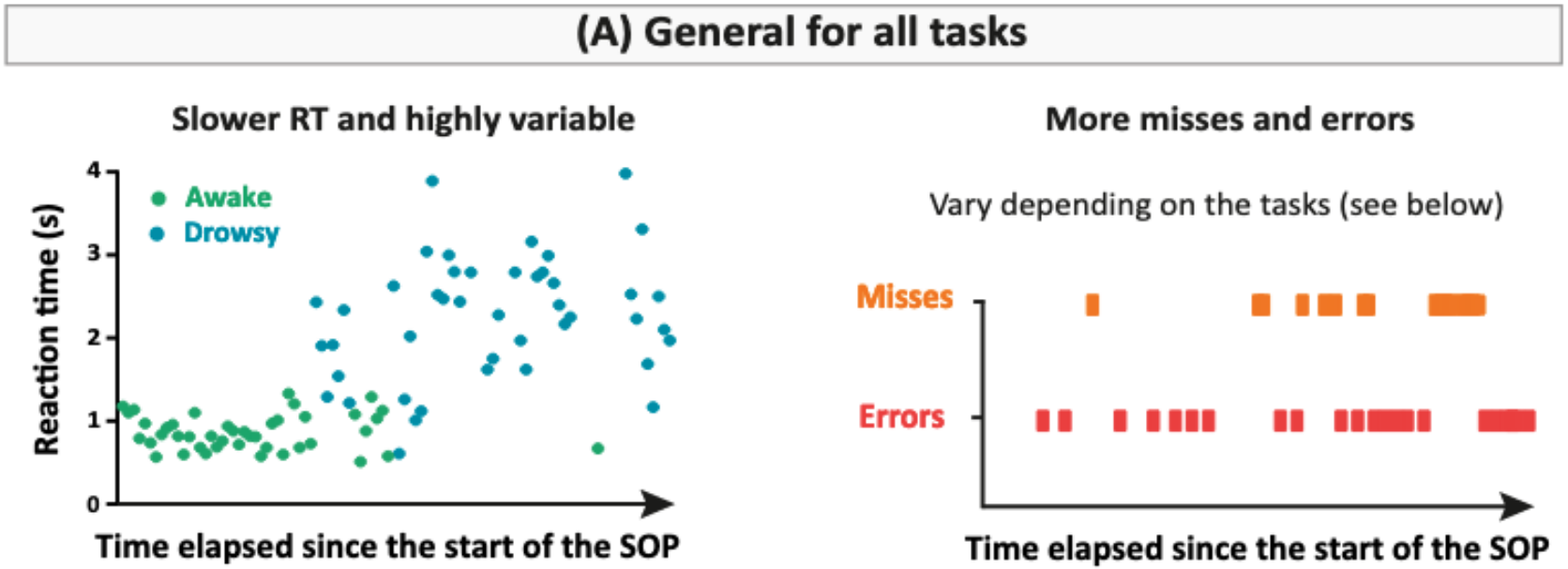
Sommeil

Réactivité minimale



Aucune période de transition n’est clairement définie entre l’éveil et le sommeil

Et pourtant …

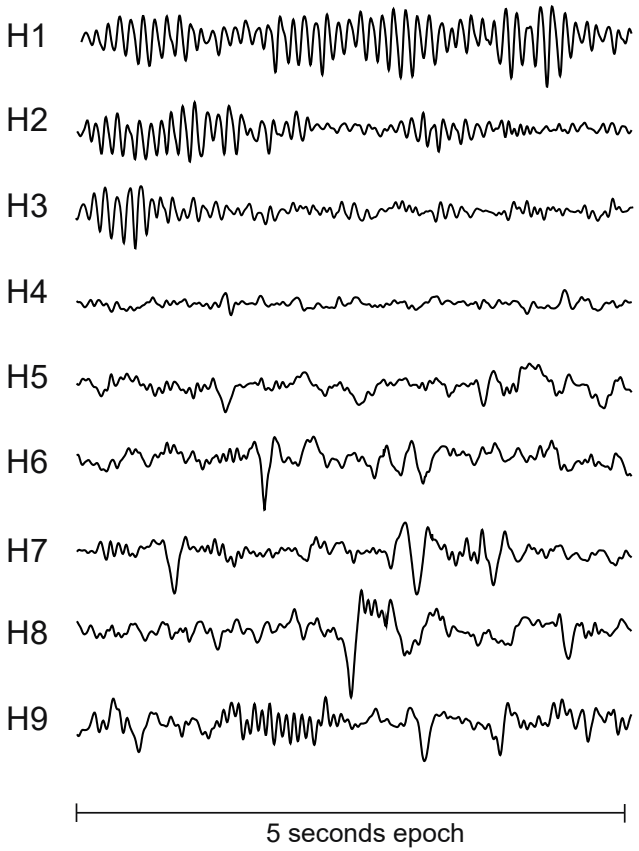


Lacaux et al, TINS 2024

Signatures électrophysiologiques

Des rythmes multiples et changeants

Stages from Hori et al. (1994)



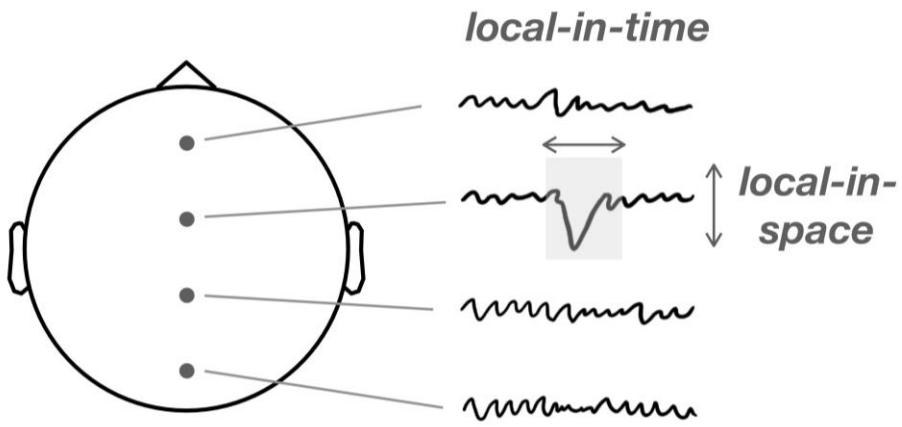
Patterns multiples et transitoires
Haute variabilité intra et inter-individuelle

Box 1. Summary of the various possible EEG modifications during the sleep onset period:

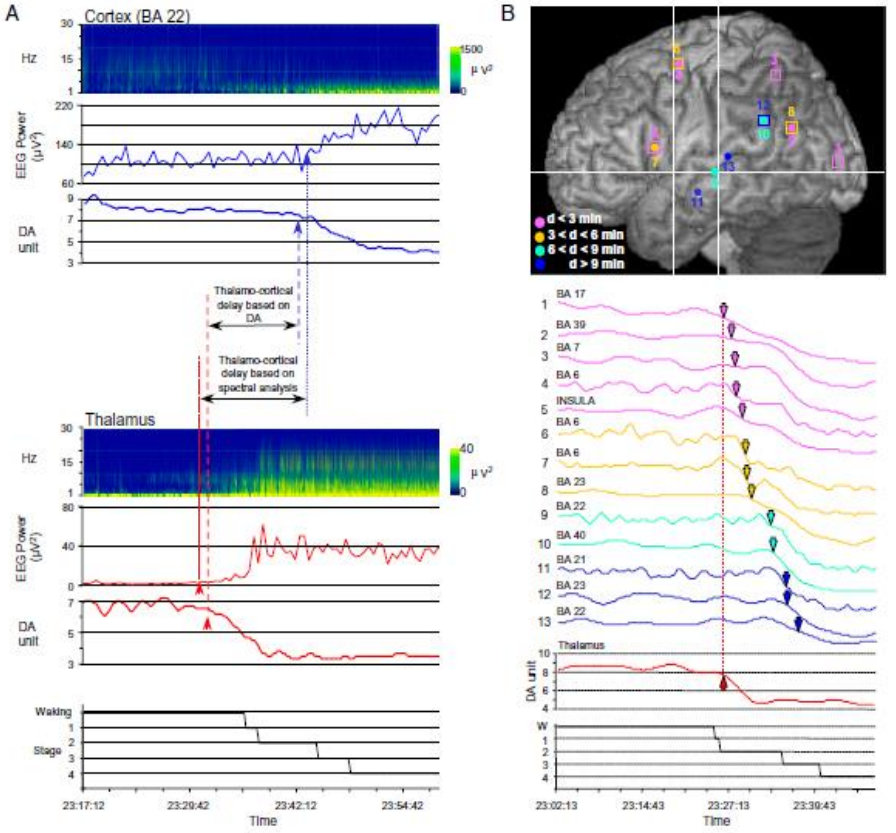
i) Changes in the alpha rhythm (8–12 Hz):
a. Amplitude increase and hyper-synchronization
b. Diffusion in central and anterior regions
c. Slow-down
d. Fragmentation
e. Amplitude decrease
f. Theta (4–7 Hz) or delta (< 4 Hz) concomitant with alpha (within the same area or in different ones, slowdowns are often more anterior or temporal).
ii) Low amplitude (< 20 μV), mixed rhythms – "flattening"
iii) Theta rhythms, which can appear in trains
iv) Sharp waves, predominant at the vertex (negative or diphasic), isolated or in bursts
v) Incomplete K-complexes or spindles
vi) Slow, delta waves

Un endormissement loco-régional

Existence de ’sommeils’ locaux



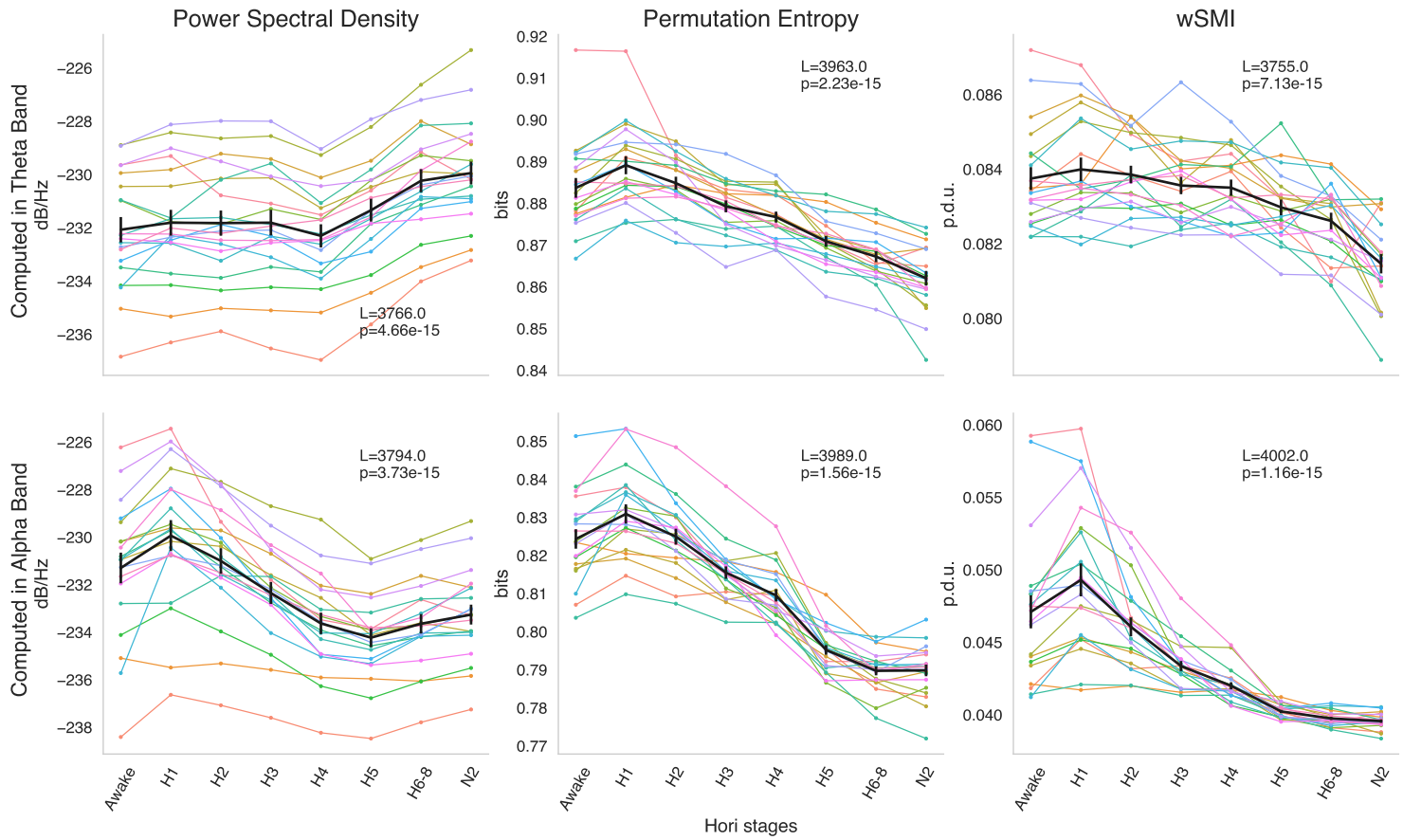
- Les aires corticales se désactivent de manière progressive et hétérogène
- Le thalamus ‘s’éteint’ avant le cortex



Andrillon et al, Front. Neurosc. 2019

Magnin et al, PNAS 2010

Connectivité et information



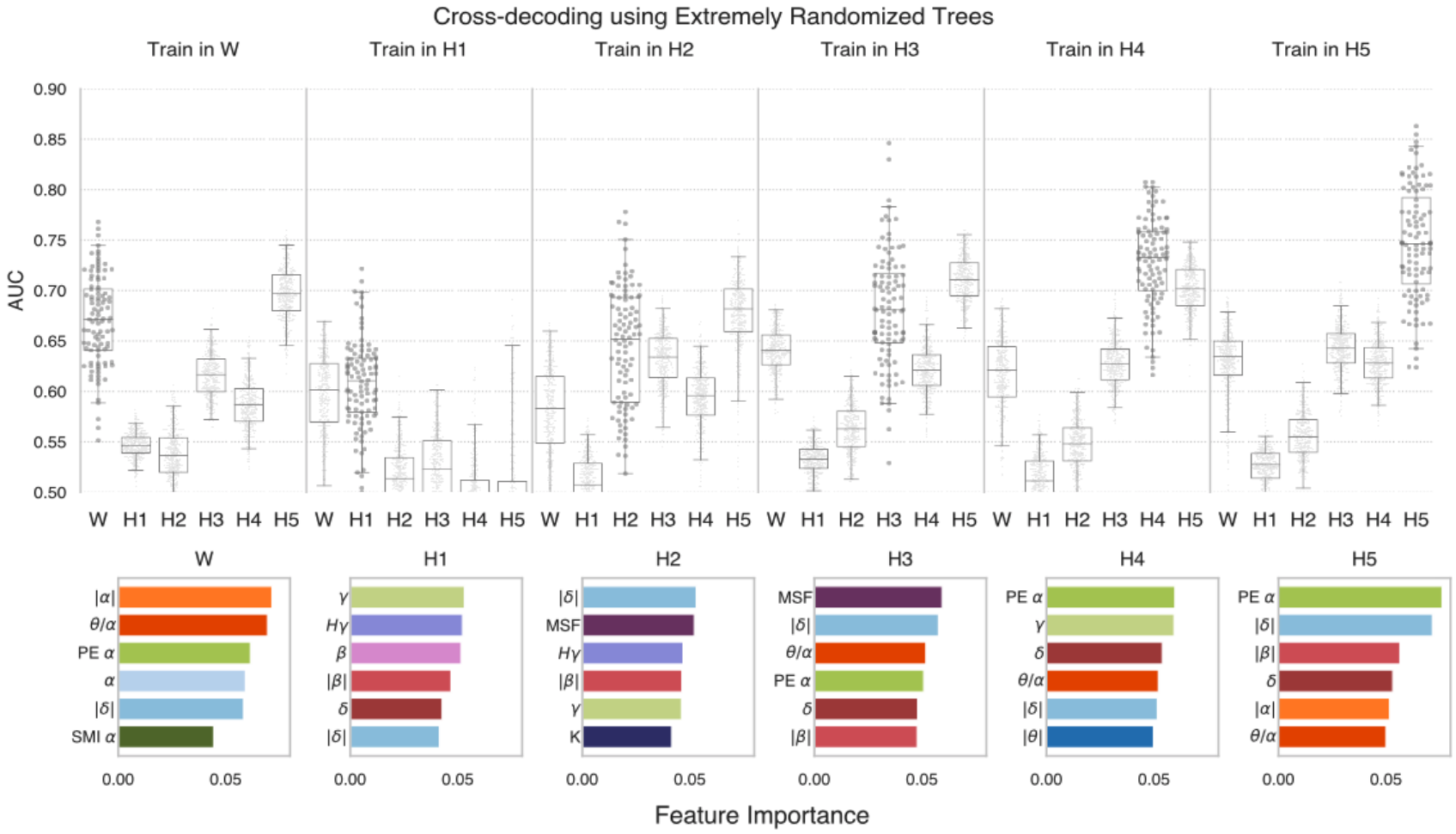
Theta power increase, but the information embedded in this theta decreased

> this theta did not support complex information usually associated with consciousness

Alpha power, information and connectivity decrease with drowsiness

Strauss et al, NeuroImage 2022

Des états multiples aux caractéristiques différentes



Responsiveness during Hori stages can be decoded from the ongoing brain state prior to the stimuli

Decoding of responsiveness can be generalized from one stage to the other in most of the stages, but with clear differences between them

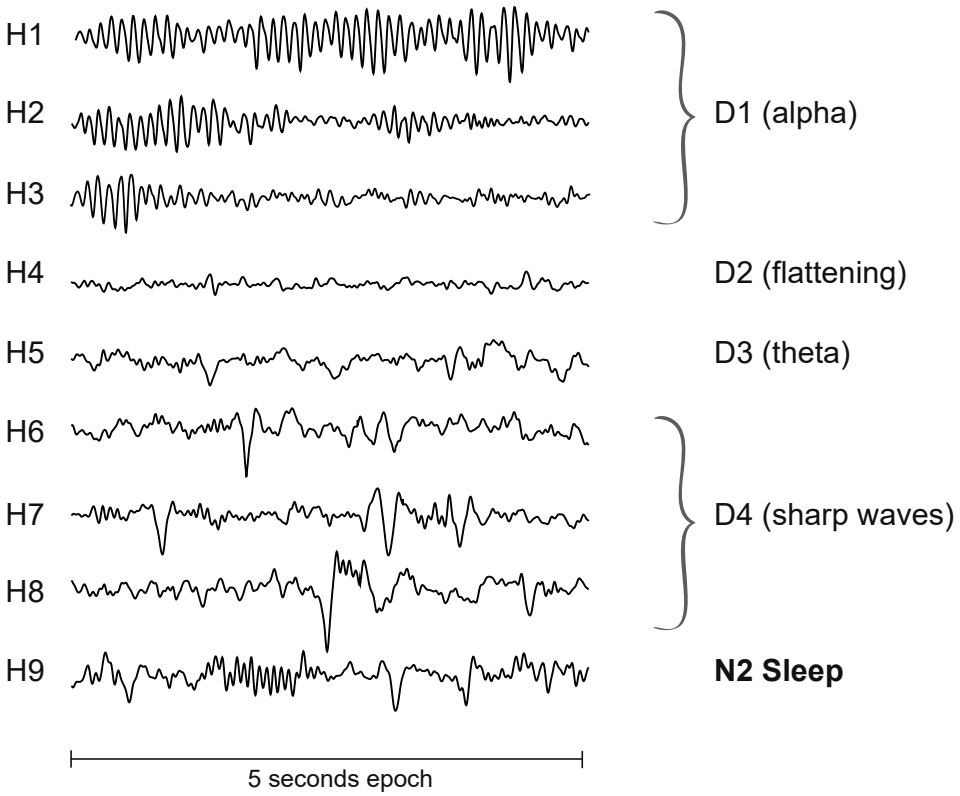
Each drowsiness stage is different from the others

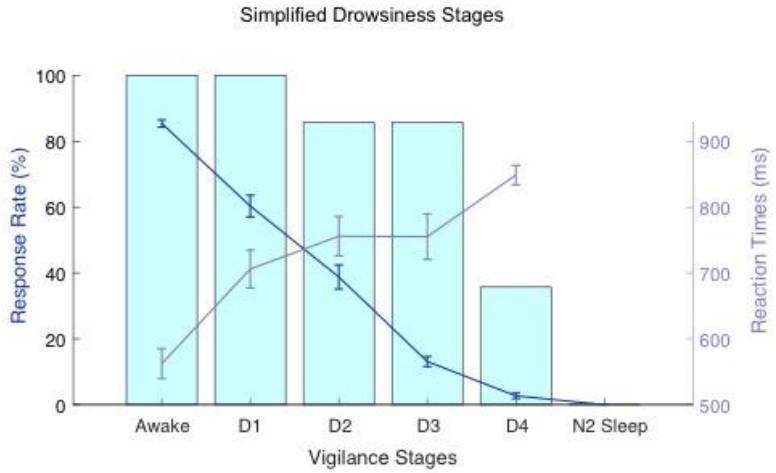
Strauss et al, NeuroImage 2022

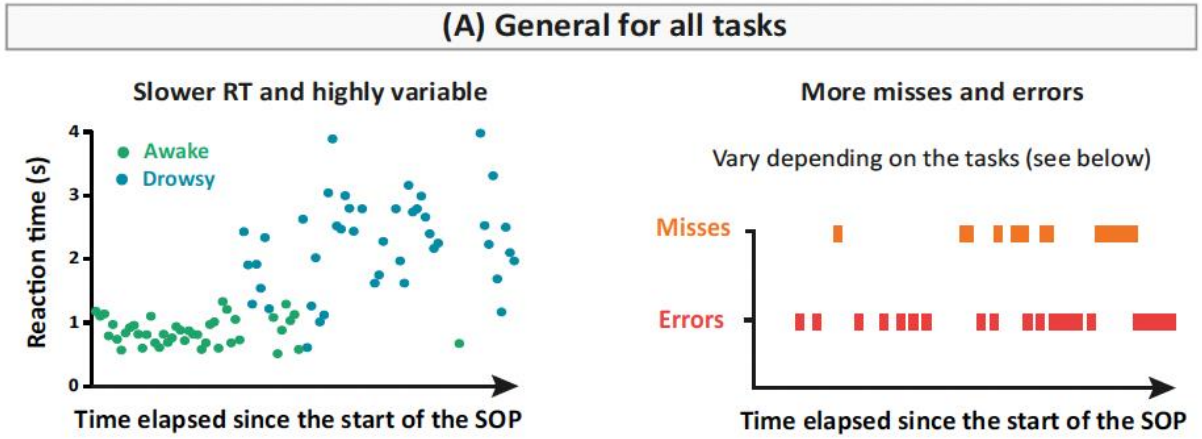
Réactivité à l’environnement

Réactivité à l'environnement

Marqueurs comportementaux







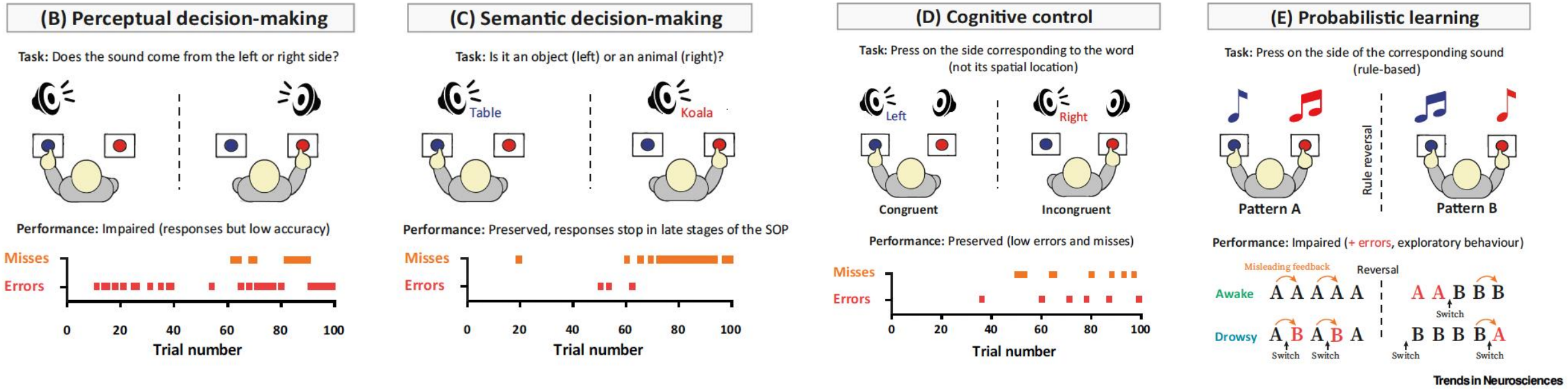
Strauss et al, NeuroImage 2022

Lacaux et al, TINS 2024

Changements cognitifs

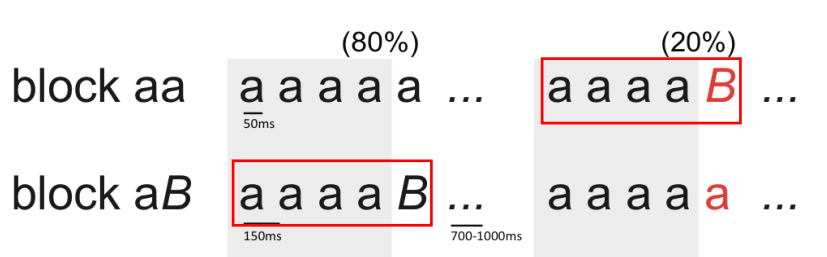
Changements cognitifs

Les fonctions cognitives subissent d'importantes modifications dès l'endormissement



Lacaux et al, TINS 2024

Changements cognitifs

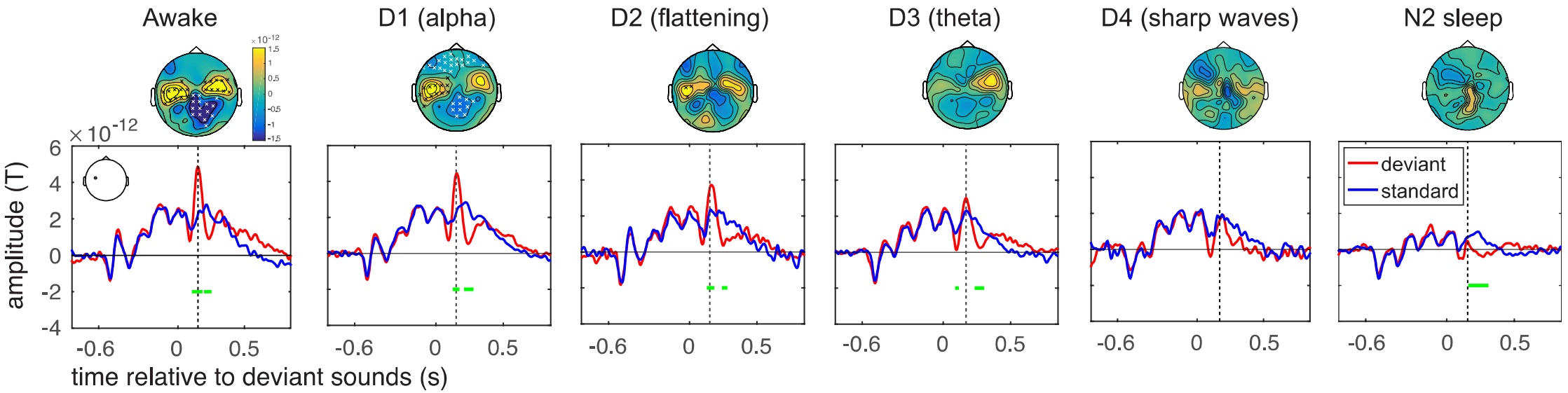


RESPONSE TO DEVIANCY
LOCAL DEVIANTS (Mismatch)
global deviants (P300)

Codage prédictif: detection de deviants (MMN)

Disparition progressive de la 'Mismatch Negativity'

Local Mismatch

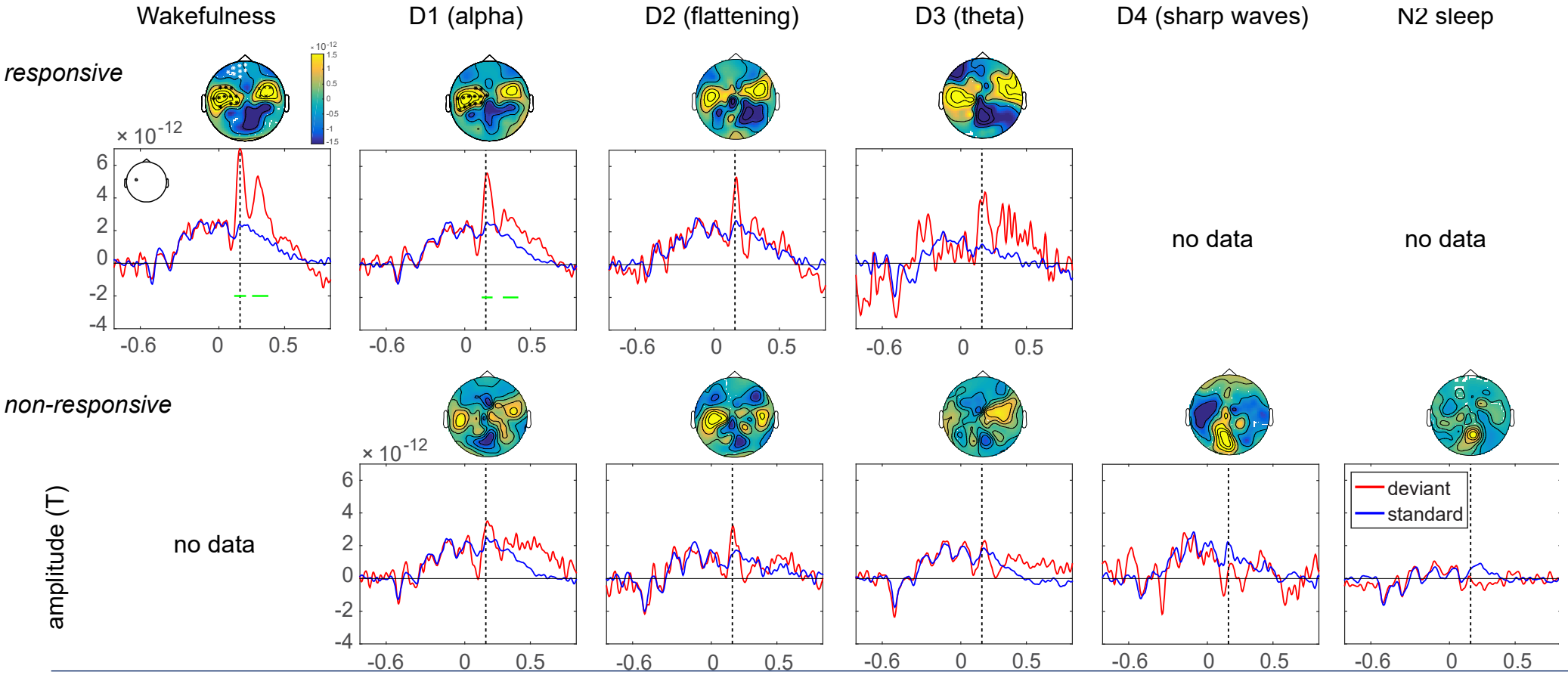


Strauss et al, NeuroImage 2022

Results

Evoked responses to Local deviants

Local Deviance and responsiveness (aaaB vs aaaa)



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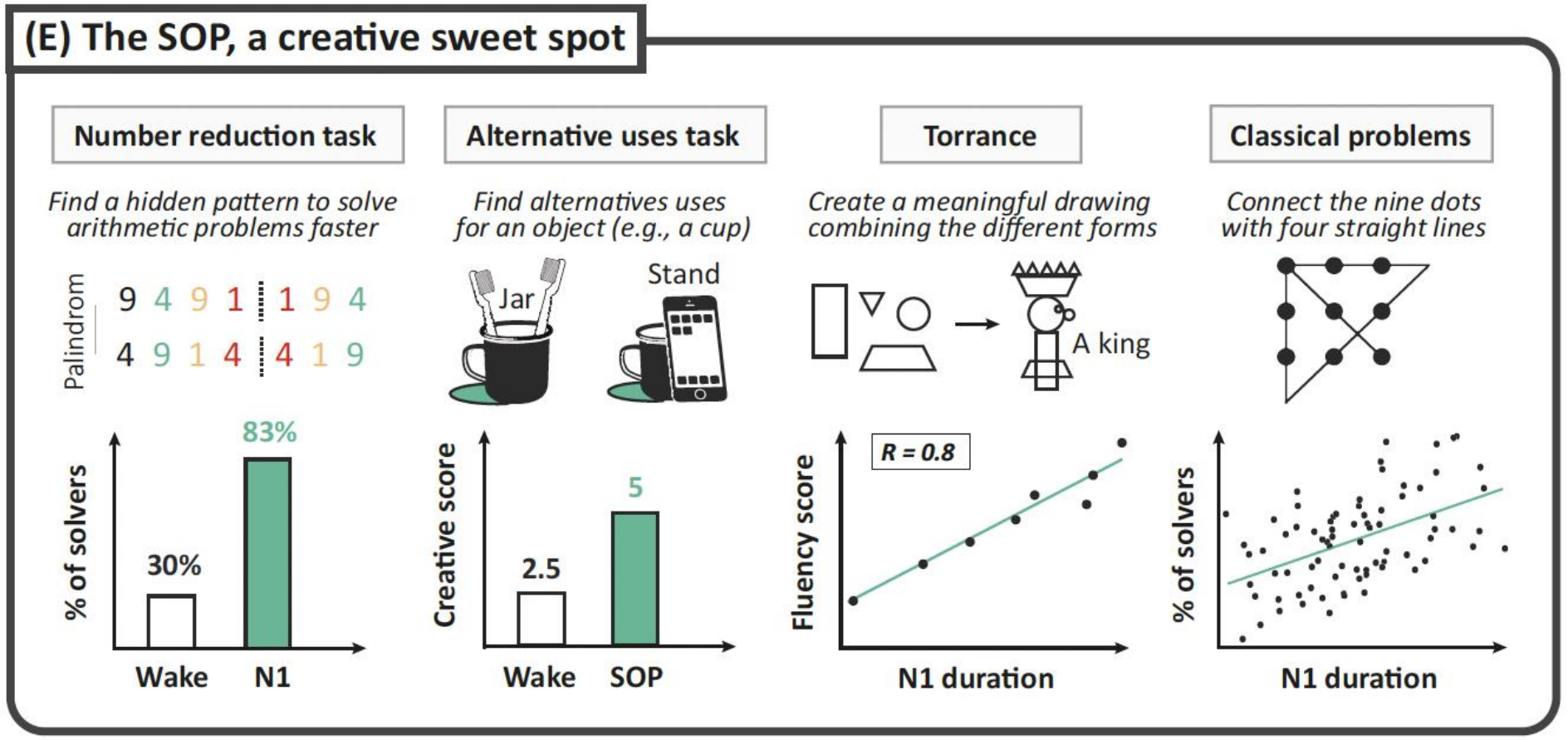
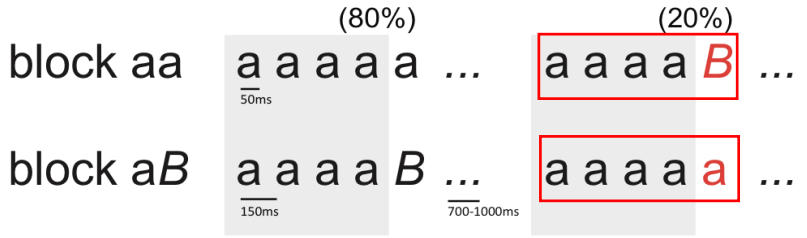


Lacaux et al, TINS 2024

Experience subjective

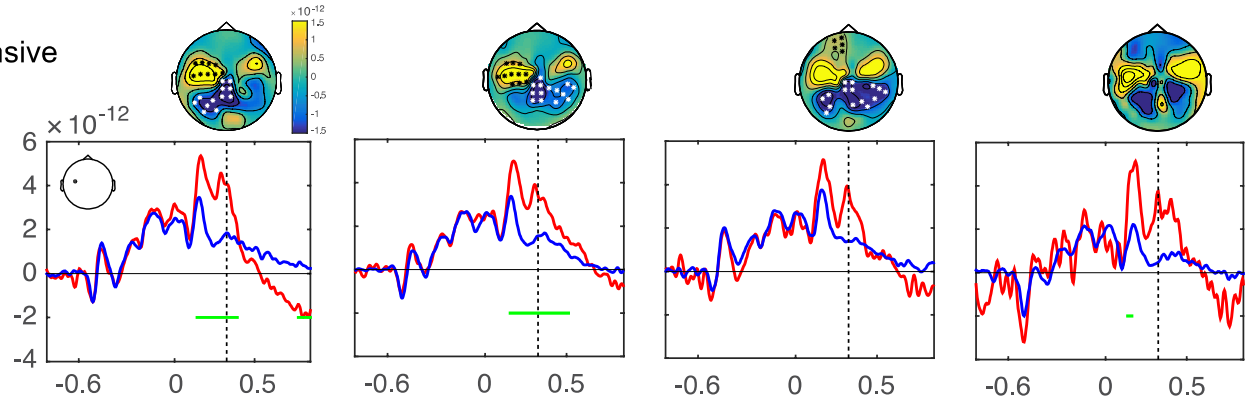
Conscience et réactivité à l'environnement

P300



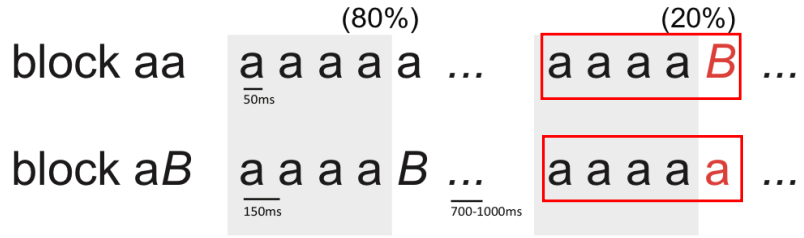
RESPONSE TO DEVIANCY
LOCAL DEVIANTS (Mismatch)
global deviants (P300)

Global Deviance

	Awake	D1 (alpha)	D2 (flattening)	D3 (theta)	D4 (sharp waves)	N2 sleep
responsive						
Responsive					no data	no data

Conscience et réactivité à l'environnement

P300



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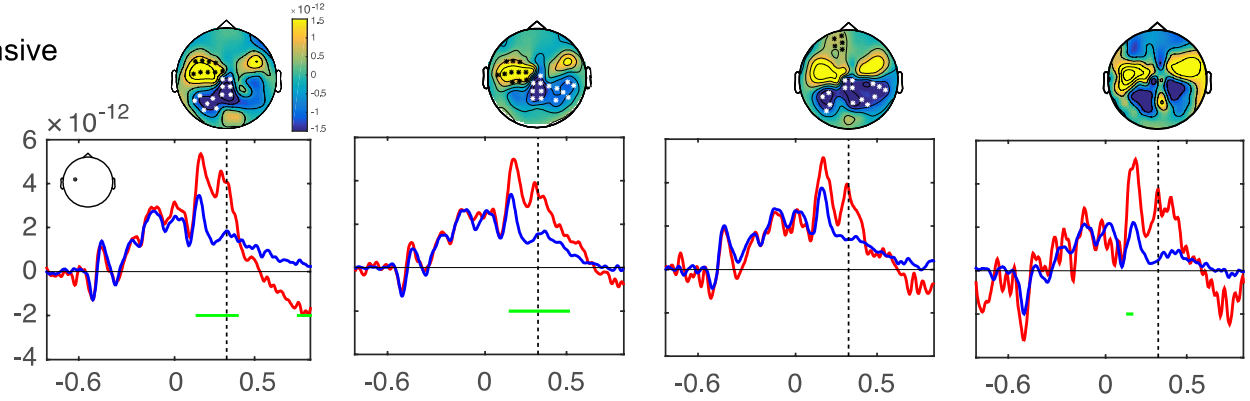
responsive						
Responsive					no data	no data

La P300 n'est présente que lorsque le participant est conscient/réactif au son, quelque soit l'état de vigilance

Strauss et al, NeuroImage 2022

Contenu mental, hallucinations hypnagogiques, perception du sommeil

Blurred perceptions, hypnagogic hallucinations

Average Recall Rate of Hypnagogic Imagery (HI%) and Average Distribution of HI for Each Sensory Modality Across EEG Stages

		Sensory modalities of HI				
EEG Stage	HI%	VIS	AUD	BOD	MS	Total
1	23.3 (1.1)[a]	73.6	12.5	12.7	1.2	100.0
2	25.8 (1.3)	75.3	14.5	8.3	1.9	100.0
3	33.5 (1.4)	77.2	14.5	7.3	1.0	100.0
4	37.7 (1.5)	82.4	12.6	5.0	0.0	100.0
5	45.7 (2.3)	91.4	5.0	3.6	0.0	100.0
6	39.8 (1.9)	95.2	2.4	2.4	0.0	100.0
7	38.7 (1.8)	93.1	3.1	3.0	0.8	100.0
8	34.6 (1.7)	90.5	2.1	7.4	0.0	100.0
9	31.9 (1.5)	91.0	1.4	7.6	0.0	100.0
Mean	34.6	85.5	7.6	6.4	0.5	100.0
SE	2.2	2.6	1.8	1.0	0.2	

NOTE: VIS: visual imagery; AUD: auditory imagery; BOD: bodily imagery; MS: miscellaneous.
[a]Figures in parentheses are standard errors (*SE*s).

Hori et al, 1994

Subjective perception of sleep usually start after the firsts sleep spindles
(Bonnet et al. 1982))

Vers des mesures fines et multidimensionnelles

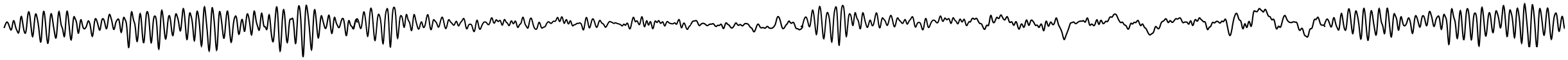
Applications cliniques

Dynamique temporelle

- **Méthodes visuelles avec meilleure granularité temporelle**

  - **Micro-sommeil**

  Suppression de l’alpha ou apparition du thêta pendant moins de 15 secondes



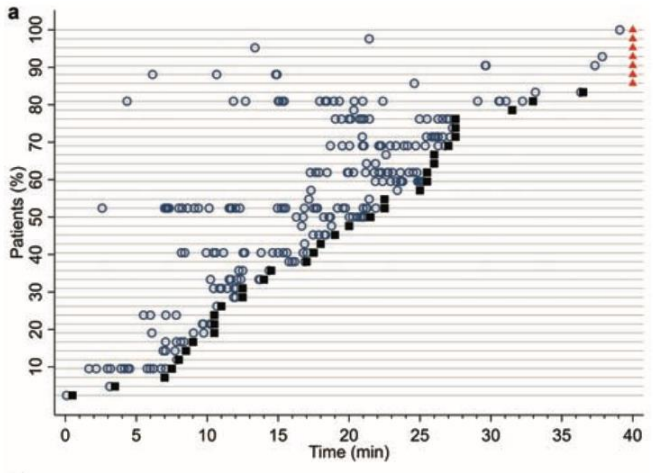
Dynamique temporelle

- **Méthodes visuelles avec meilleure granularité temporelle**

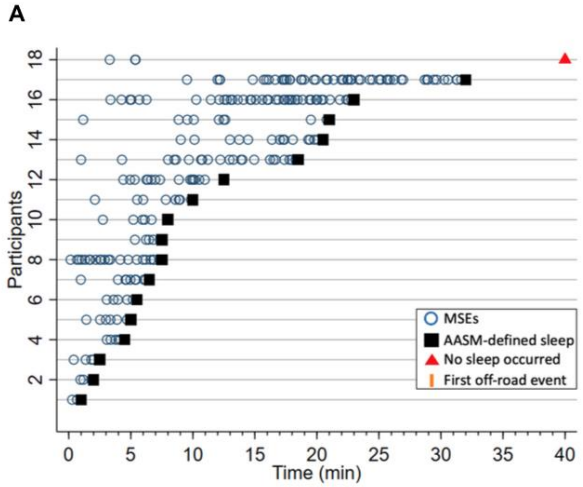
  - **Micro-sommeil** *(Hertig-Godeschalk et al. 2020, Skorucak et al. 2020, Des Champs de Boishebert et al. 2021)*

  Conduite: Micro-sleep Episodes (MSE) pendant les TME ou en conduite simulée, TILE/narcolepsie

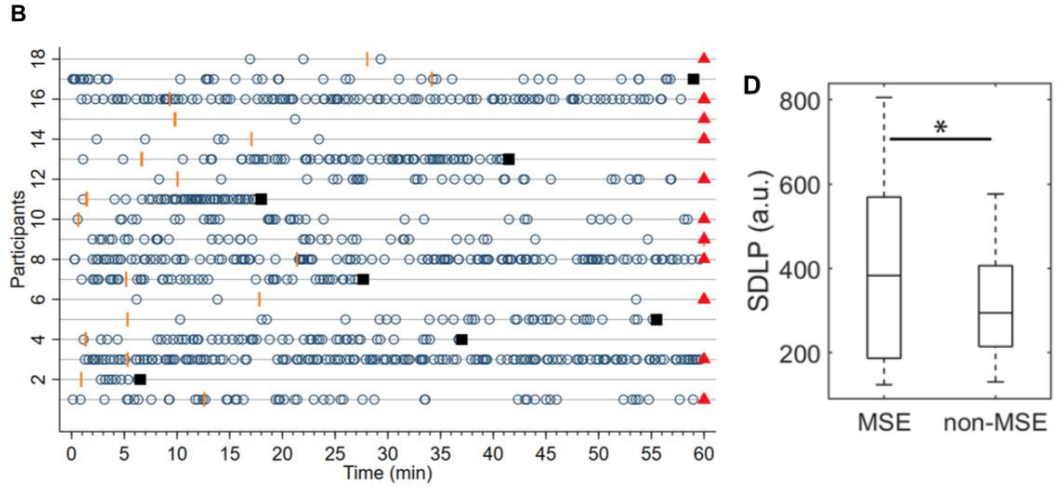
Maintenance of Wakefulness test (MWT)



MWT



Simulated driving

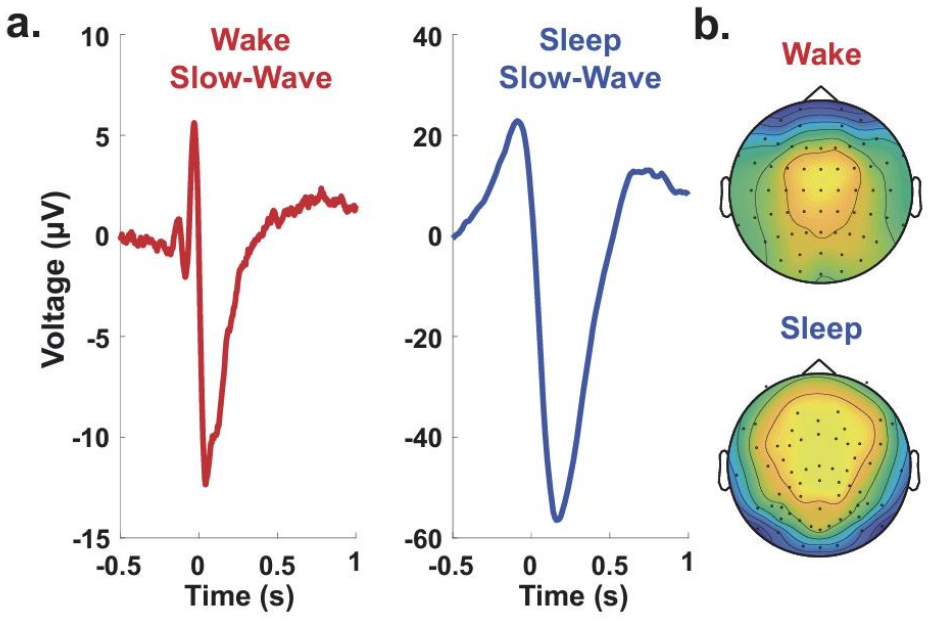


Hertig-Godeschalk et al. 2020

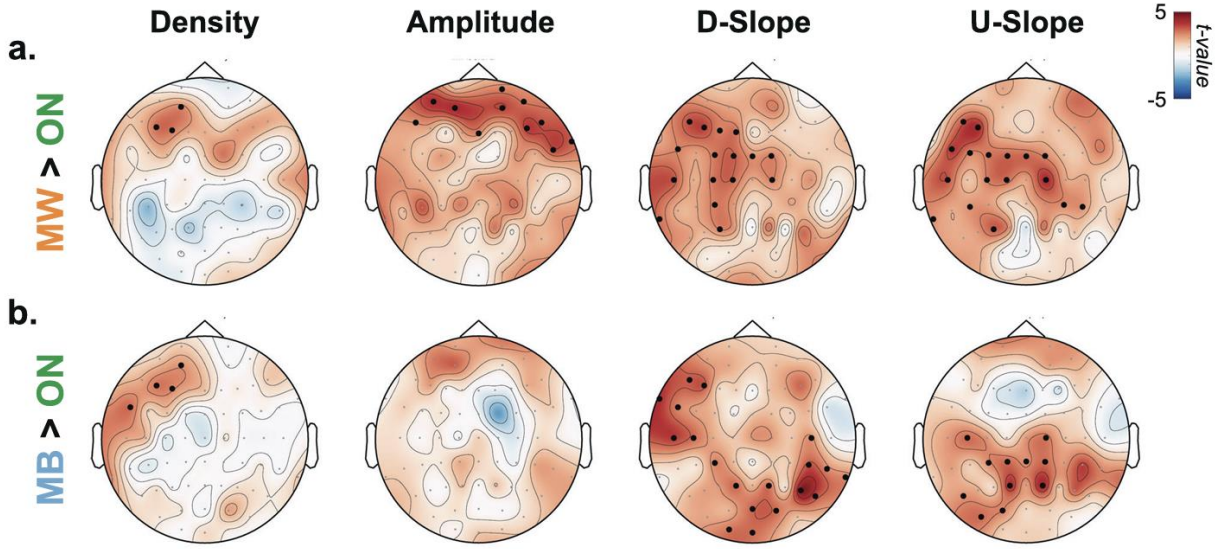
Skorucak et al. 2020

Dynamique temporelle

- **Détections automatiques à l'échelle de l'évènement**
  - **Détections d'ondes lentes à l'éveil**

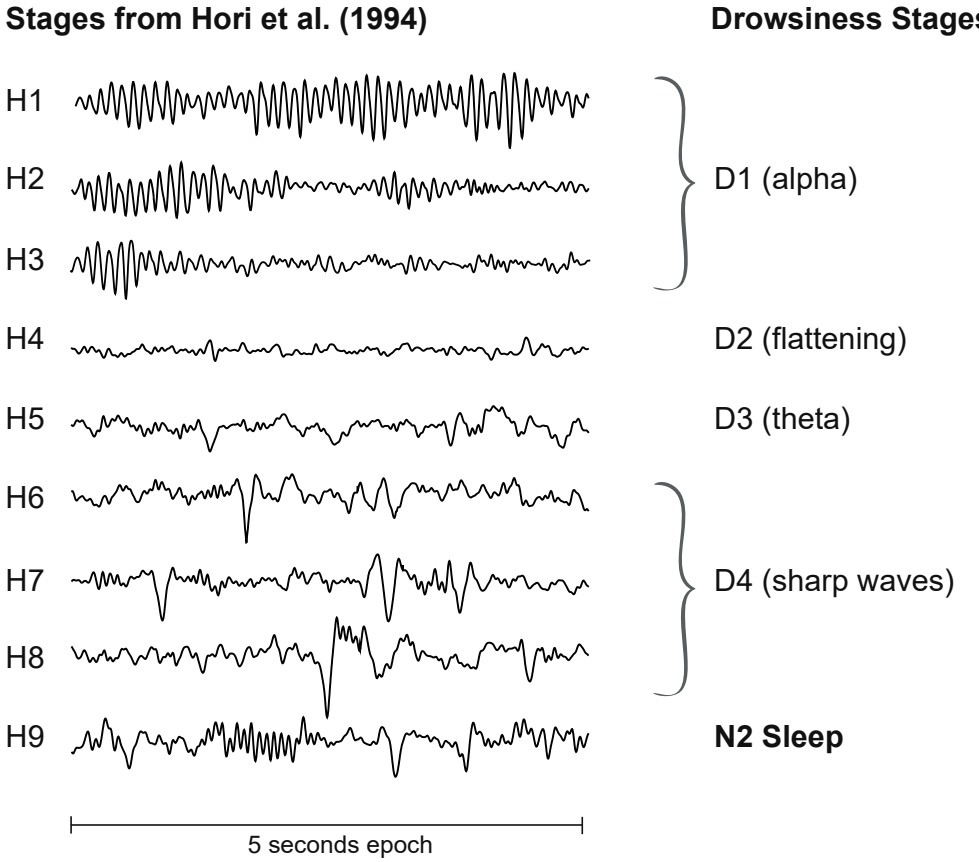


Associées au Mind Blanking et Mind Wandering

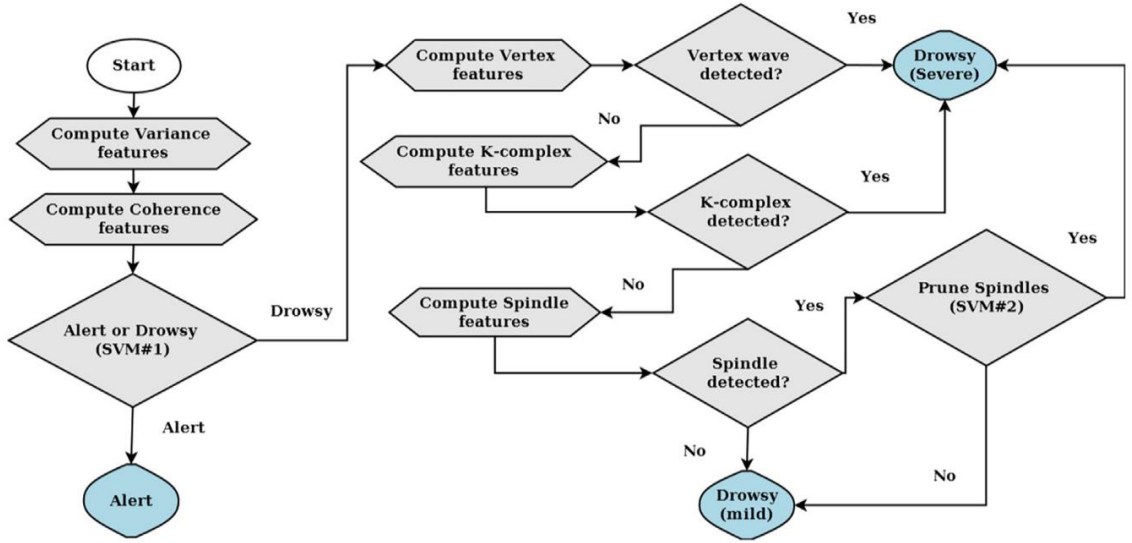


Andrillon et al. Nat Comm 2021

Profondeur de l'endormissement



Mesures automatiques basées sur les stades de Hori



Jagannathan et al. NeuroImage 2018

Profondeur de l'endormissement – marqueurs continus

Neurodegenerative disorders

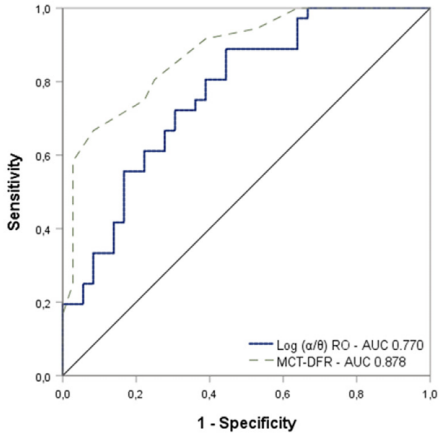
Slowing EEG activities help distinguish between

- individuals with neurodegenerative disorders and healthy controls (Massa et al. 2020, Schumacher et al. 2020, Jaramillo-Jimenez et al. 2021, Schmidt et al. 2013, Özbek et al. 2021)
- different neurodegenerative disorders such as patients with Alzheimer's and Lewy body diseases (Roks et al. 2008, Babiloni et al 2018)
- & is associated with cognitive alterations in Parkinson disease (Jaramillo-Jimenez et al. 2021)

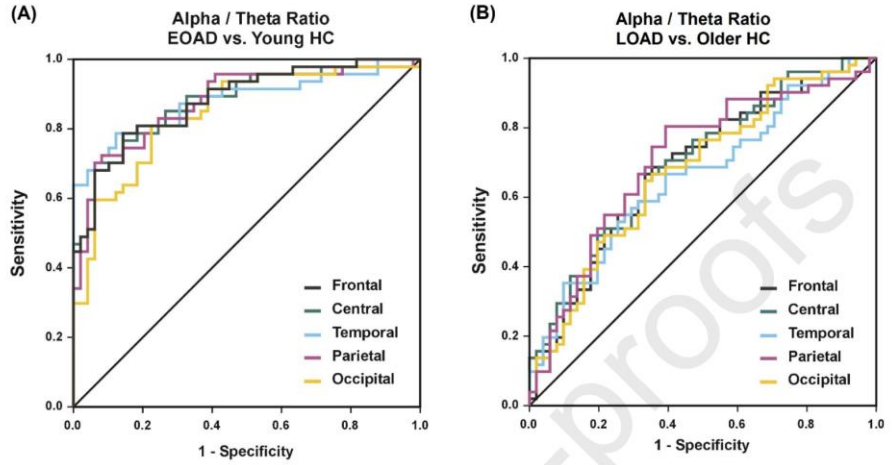
Insomnia

- Increased duration of N1 in SO misperception (Hermans et al 2019)
- Spectral characteristics of the SOP may help to distinguish between psycho-physiological insomnia, insomnia comorbid of psychiatric disorders, and healthy controls (Lamarche et al. 1997)

Log(alpha/theta) values and its accuracy to separate PD patients from HC



alpha/theta values and its accuracy to separate AD patients from HC

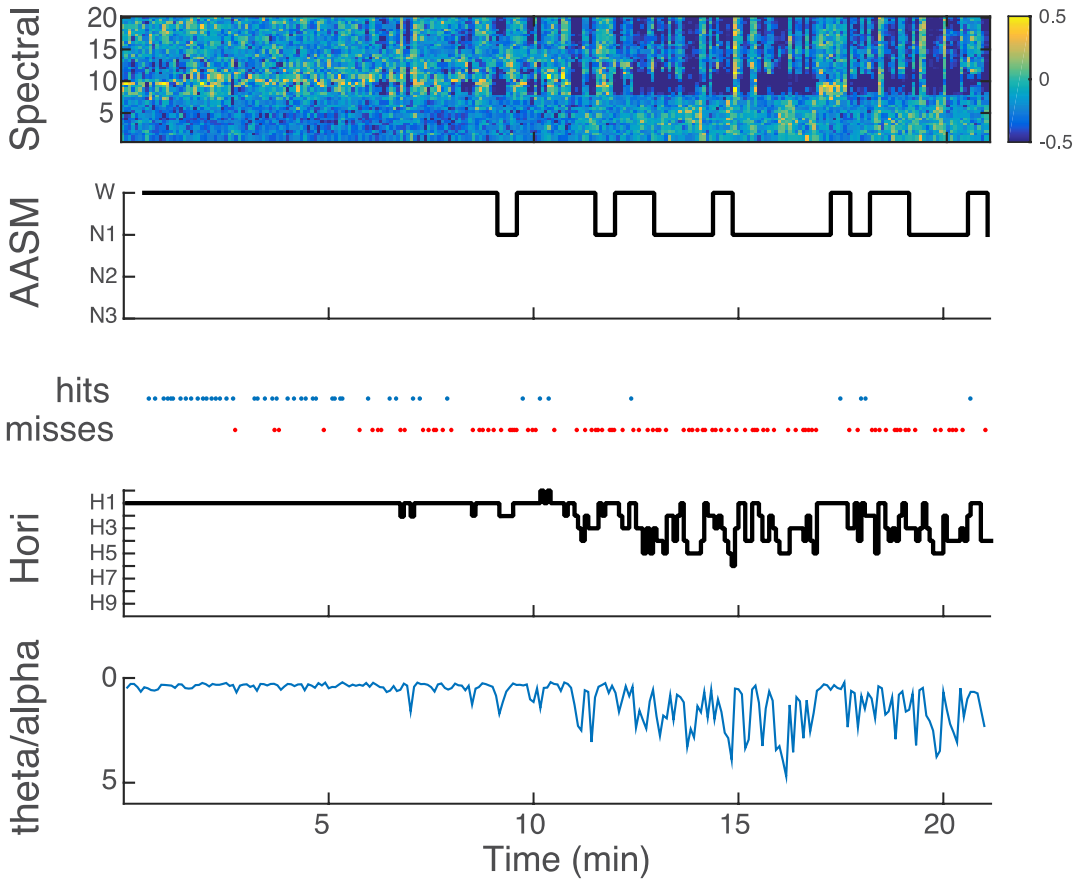


Jaramillo-Jimenez et al. 2021

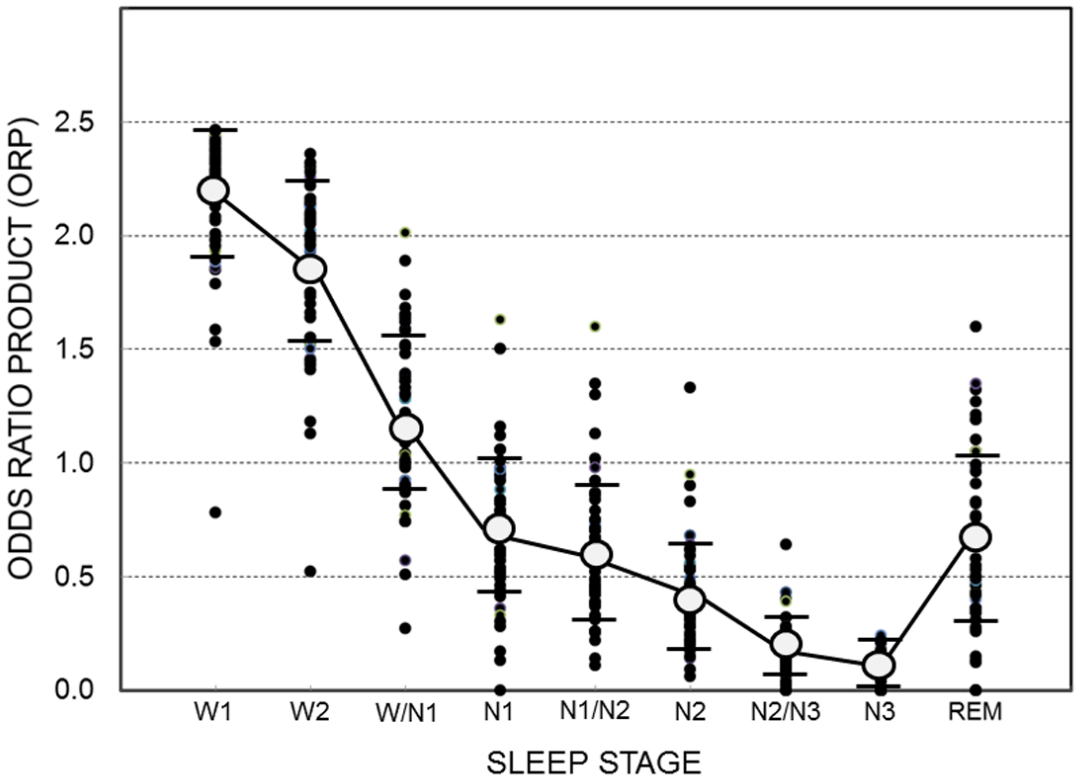
Özbek et al. 2021

Profondeur de l'endormissement – marqueurs continus

Theta-alpha ratio



ORP



3-second epochs and divided into delta, theta, alpha-sigma, and beta frequency bands.

Strauss et al. NeuroImage 2022

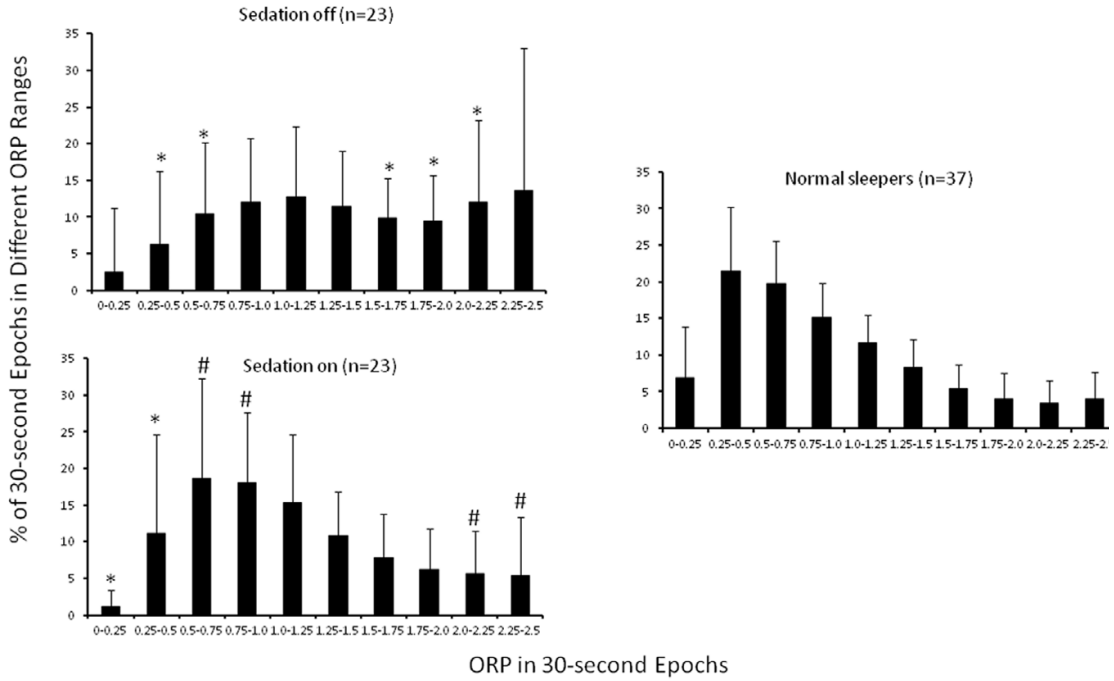
Younes et al. SLEEP 2015

Profondeur de l'endormissement – marqueurs continus

- **Odds Ratio Product (ORP)**

Profondeur du sommeil à travers la nuit

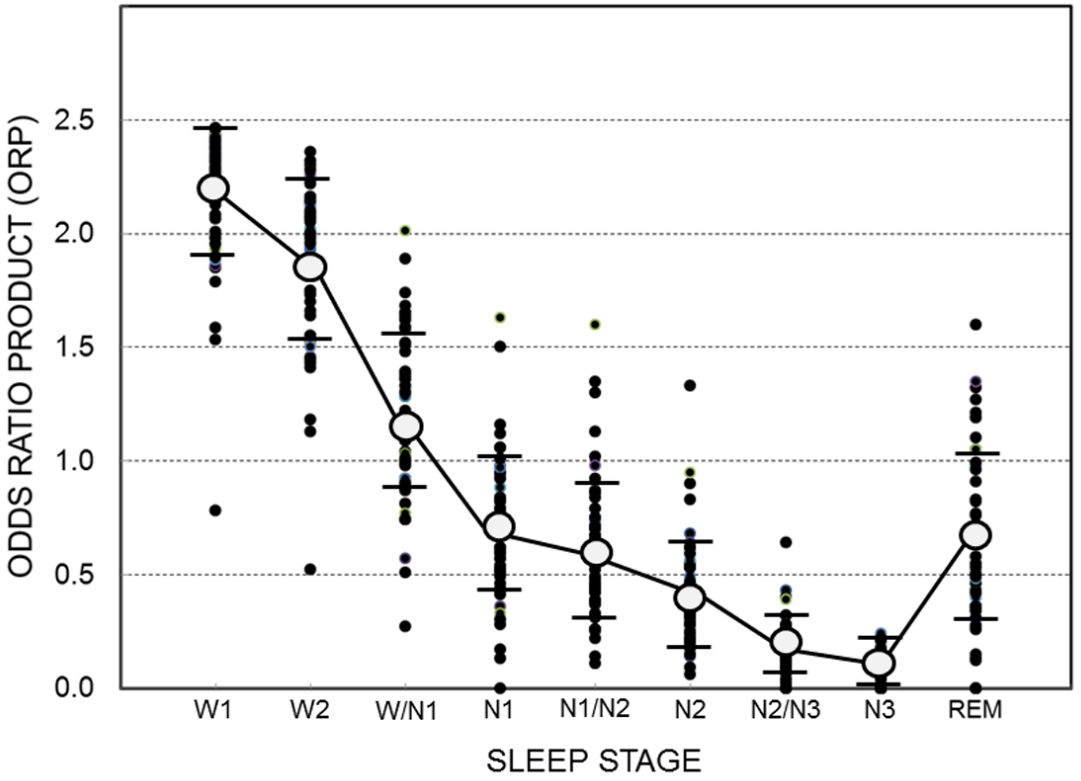
Patients en soins intensifs



Georgopoulos et al. Critical Care Exploration 2021

Review: Younes Front. Neuro. 2023

ORP



3-second epochs and divided into delta, theta, alpha-sigma, and beta frequency bands.

Younes et al. SLEEP 2015

Caractérisation des différents états de vigilance et d'activité cérébrale

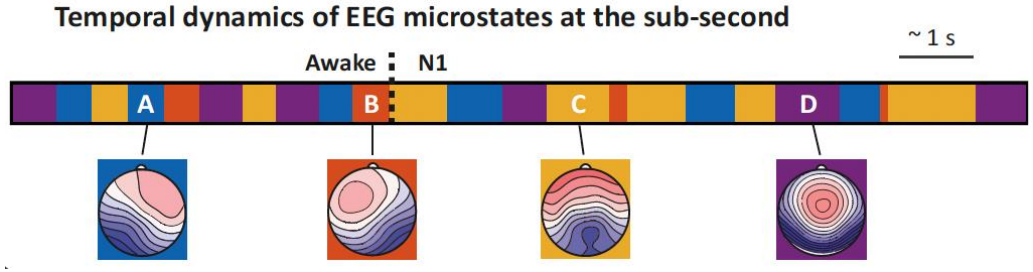
- **Microstates**

Etats d'activité cérébrale stable transitoires (50-100 ms)

impliquent des activités synchronisées aux seins de réseaux à longue distance

4 à 5 (<10) topographies dominantes

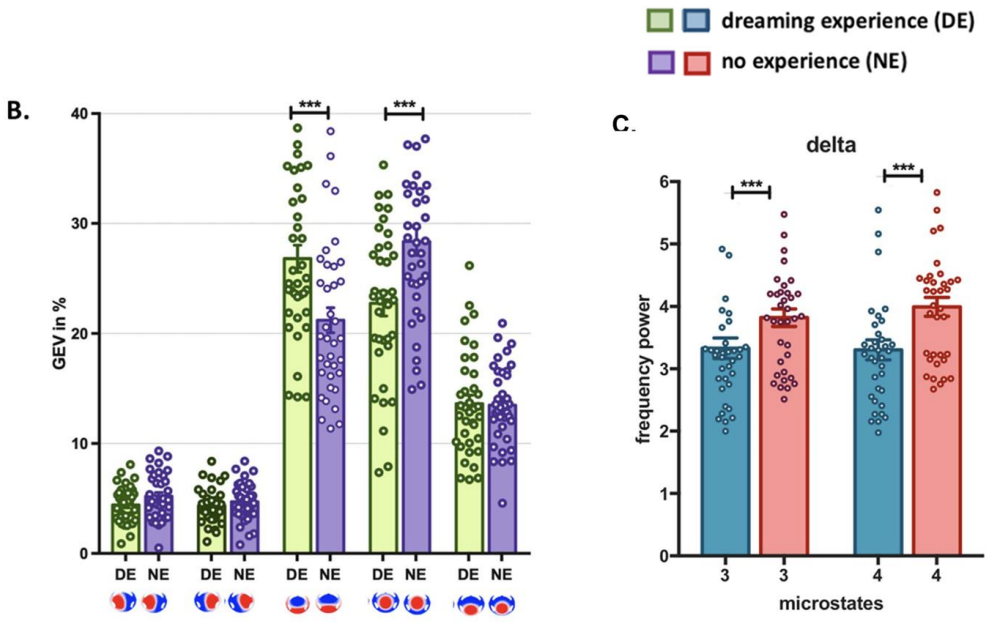
L'occurrence de ces micro-états, leur durée et leurs transitions diffèrent en fonction des états cognitifs et de conscience
(Rev. Michel et al. NeuroImage 2018)

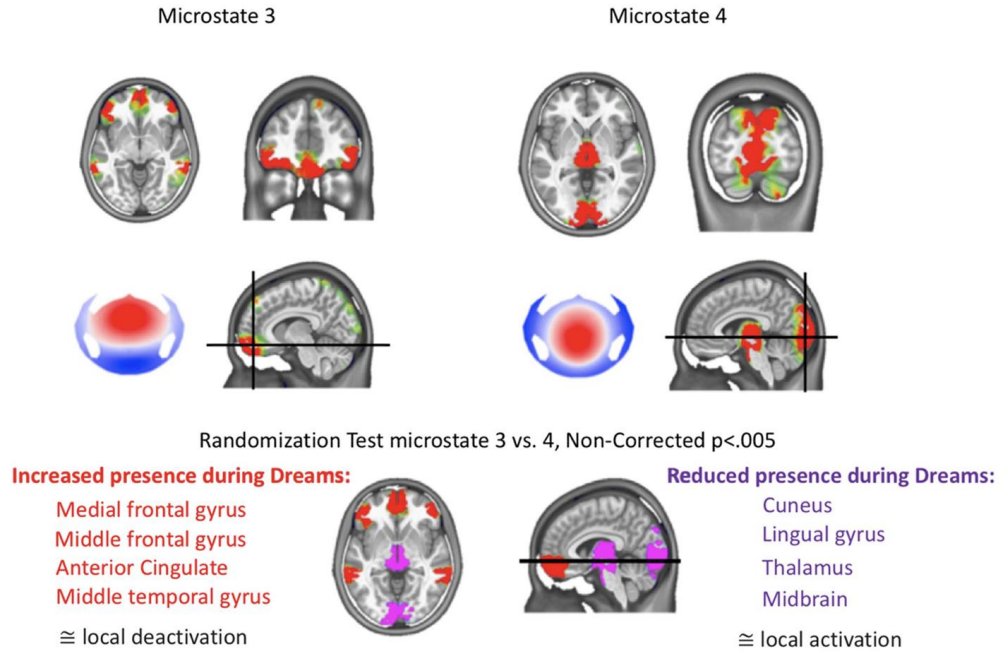


Caractérisation des différents états de vigilance et d'activité cérébrale

- **Microstates**

Signature de l'expérience onirique en sommeil lent

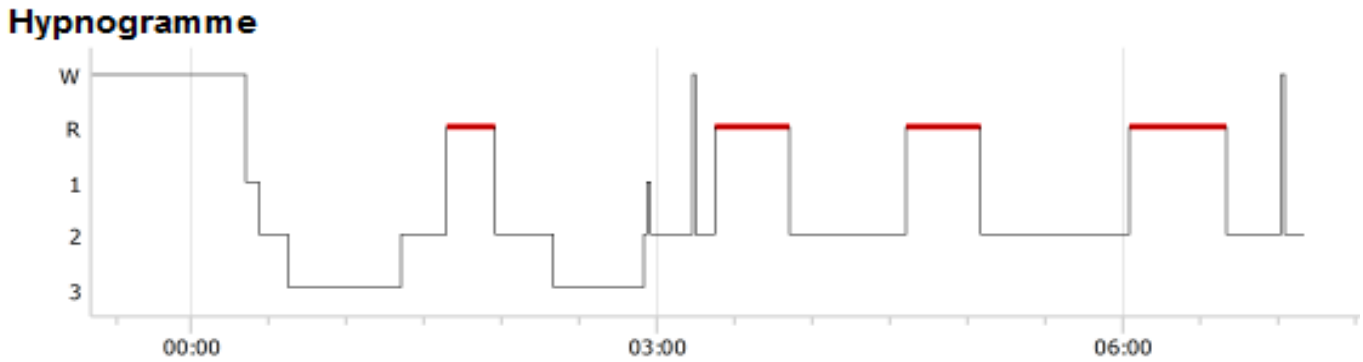




Bréchet et al, Sci. Rep. 2020

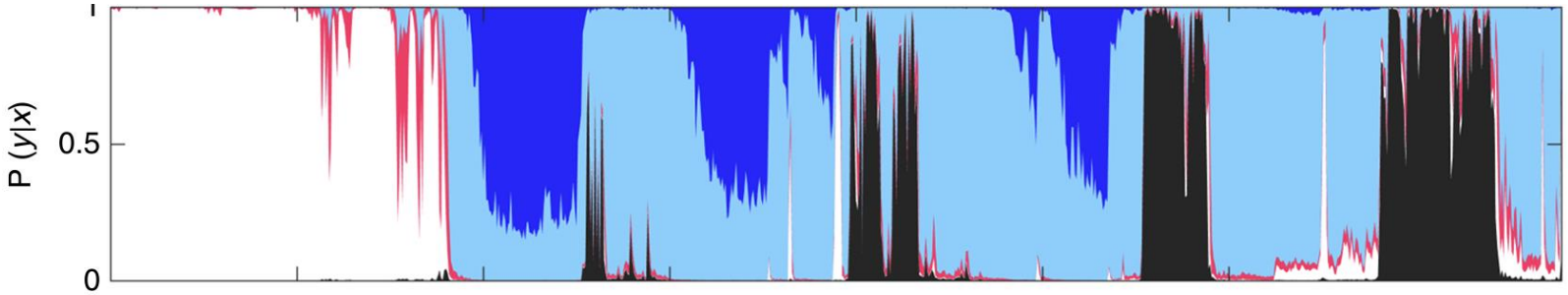
Complexité/mixité du sommeil

- Hypnodensités



Complexité/mixité du sommeil

- Hypnodensités

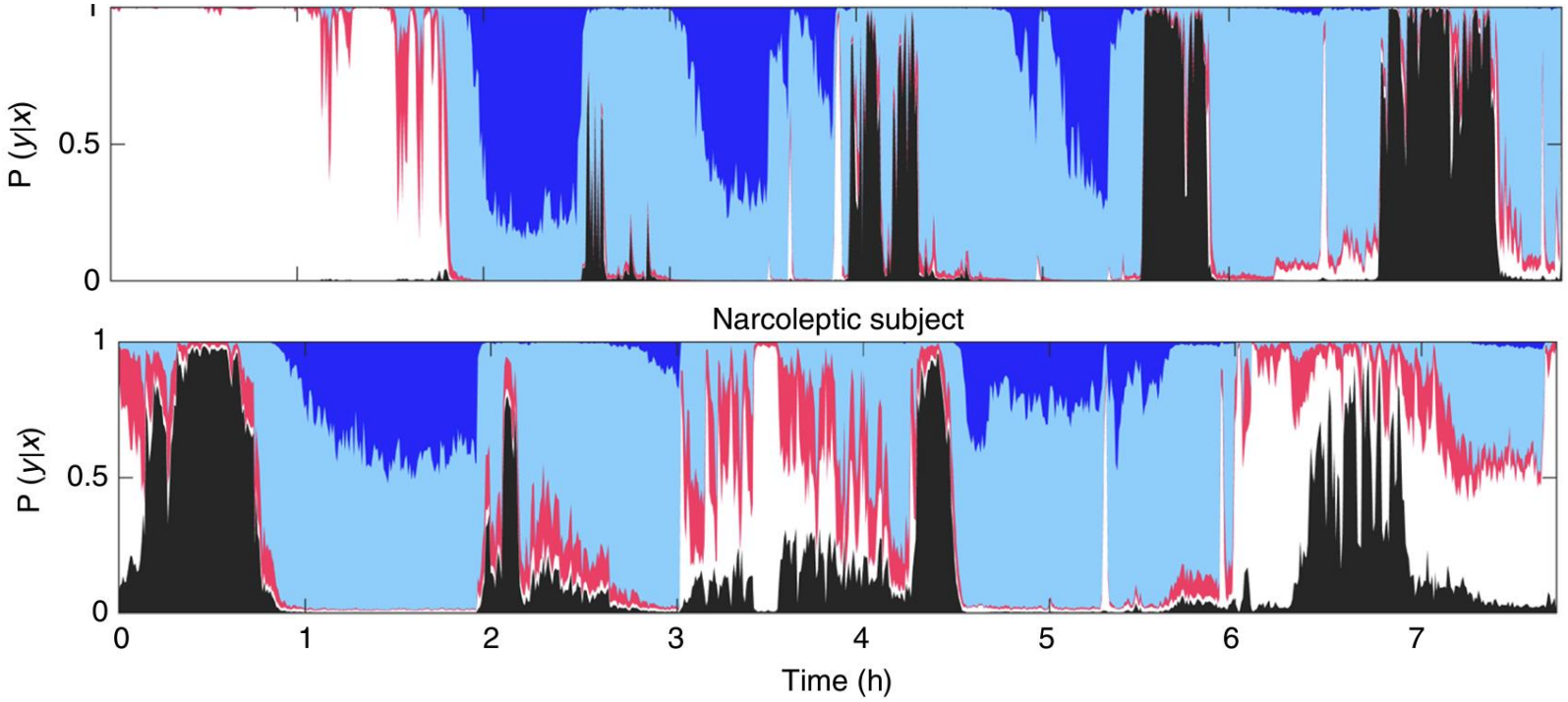


Machine learning: algorithme qui apprend à distinguer les différents stades
Pour chaque époque, probabilité d'appartenance à chaque stade de sommeil

Stephansen et al, Nat. Comm. 2018

Complexité/mixité du sommeil

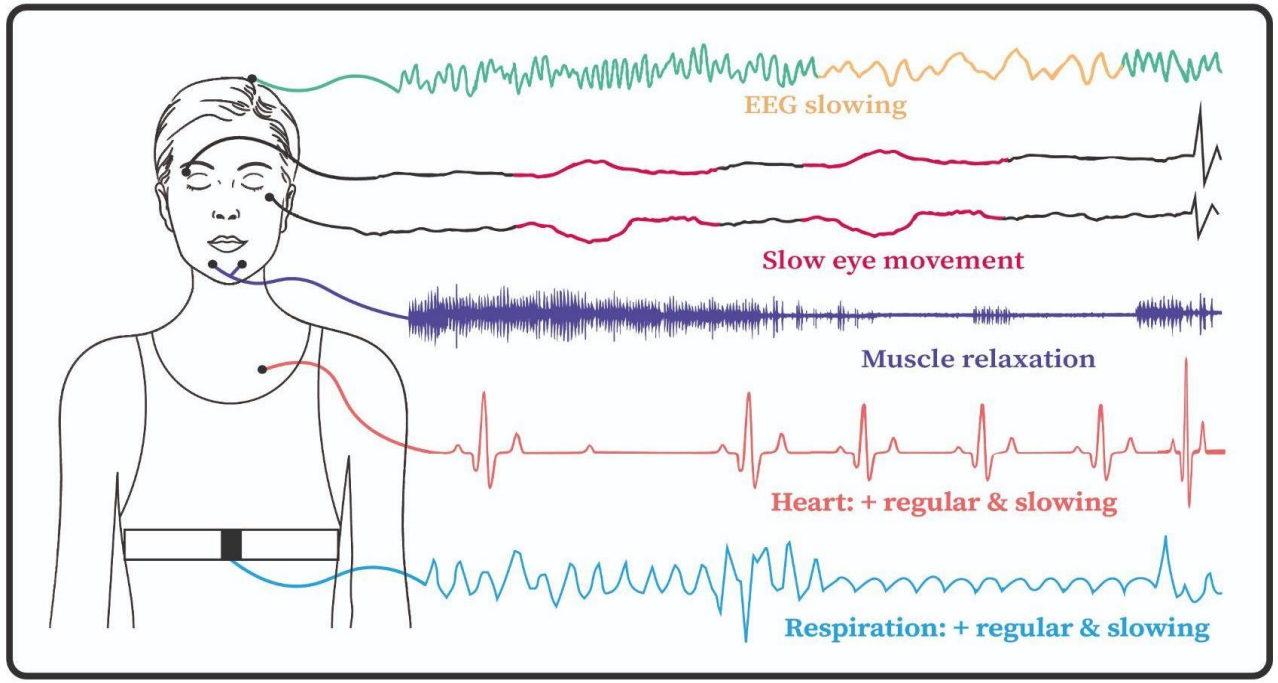
- Hypnodensités dans la narcolepsie



Stephansen et al, Nat. Comm. 2018

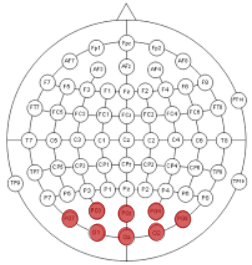
Intégrer les différents signaux physiologiques

- **Slow eye movements** (SEMs, from 0.2 to 0.6 Hz), in the early stages of the SOP (Porte et al. 2004)
- **Pupil** diameter (Maccora et al. 2018)
- **EMG** activity decreases during the SOP (Mezzanotte et al.1998; Prerau et al. 2014)
- Decline in **ventilation** (Colrain et al. 1987),
- **Heart rate** (Pivik, 1996) and
- **Electrodermal** changes (Hori 1982)



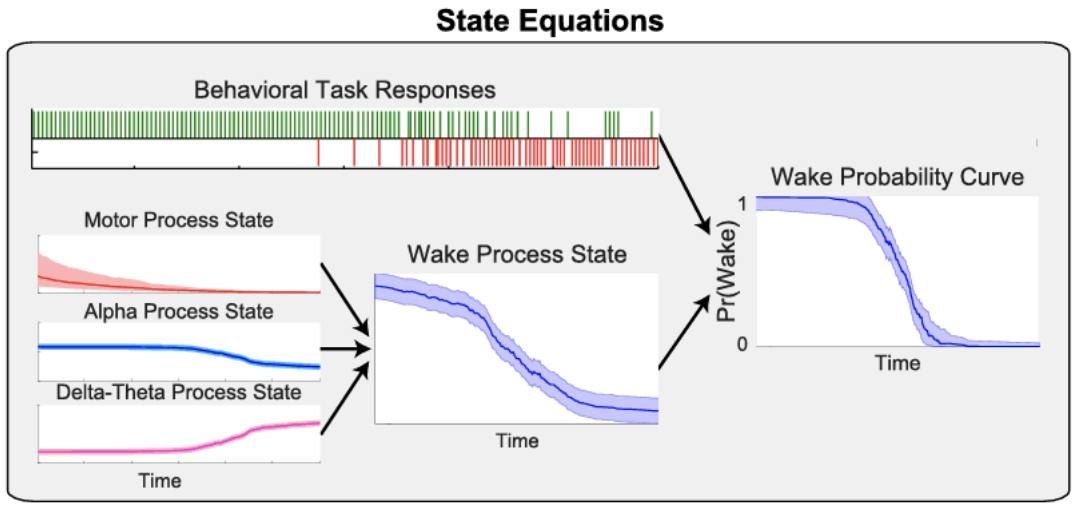
Lacaux et al. PsyArXiv 2023

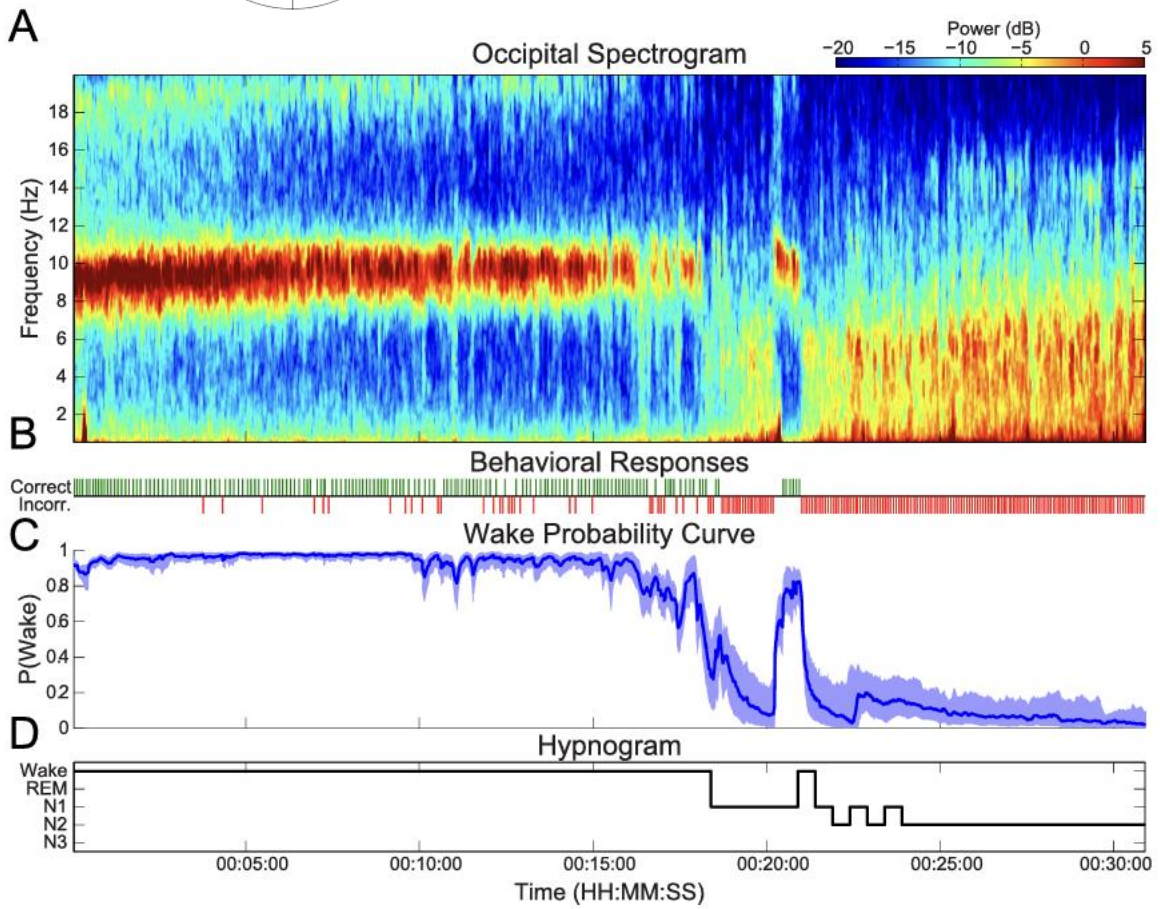
Les approaches multidimensionnelles



Intégrer les différents signaux physiologiques

Ex: Spectral and EMG markers > Wake probability curve (Prerau et al. 2014)





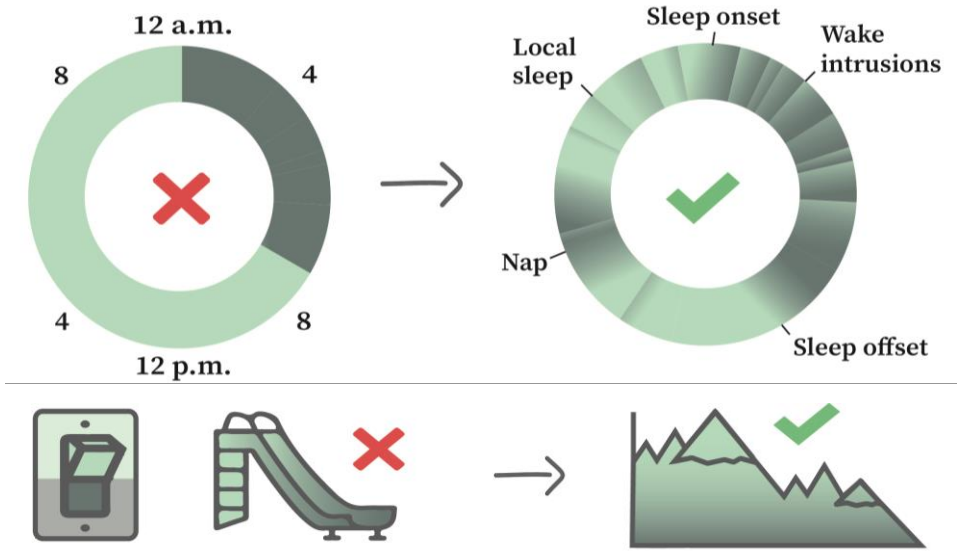
Prerau et al. Plos Comp. Biol. 2014

Conclusion: Sortir de la dichotomie veille/sommeil (et du choix forcé)

- Richesse de la transition veille-sommeil

- Multiplicité des états de vigilance
  - profondeur variable, fluctuations, transitions, …
- Mixité des états de vigilance
  - Le cerveau ne dort pas de la même façon à travers toutes ses régions

- Multiplicité des états cognitifs, perceptifs, …



➢ Intérêt clinique d'une meilleure reconnaissance de cette période de transition et du développement de nouveaux marqueurs

Inserm

Institut national
de la santé et de la recherche médicale

Merci pour votre attention

… et votre vigilance

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