Age- and sleep-related changes in brain plasticity and brain architecture in relation with cognition

Julie Carrier, Ph.D.

Département de psychologie, Université de Montréal

Research Center, Institut universitaire de gériatrie de Montréal

Center for Advanced Research in Sleep Medicine

Hôpital du Sacré-Cœur de Montréal

ESRS Sleep Science School 2019

Fonds de recherche Nature et technologies Québec

CIHR IRSC

CRSNG NSERC

Fonds de la recherche en santé Québec

Demystifying sleep in aging: towards new diagnostic, preventive, and therapeutic targets

- Targeting cerebral mechanisms underlying age-related changes in sleep and circadian rhythms is crucial to develop ***preventive and therapeutic interventions adapted for older individuals***.

- Sleeping brain is a proxy of cognitive integrity in older individuals and may be used as ***a biomarker of neurodegeneration***.

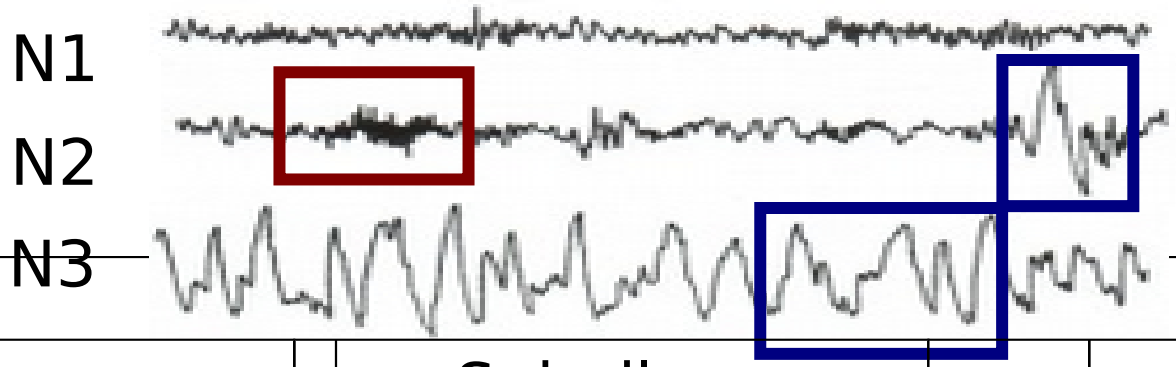
- **Improving sleep** in the older population may slow down the aging process and neurodegeneration (cognition, oxidative stress, inflammation, amyloid).

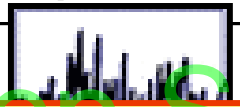
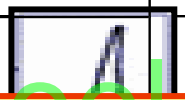
During adulthood, increasing age is associated with…

- Earlier bedtimes and waketimes
- Less time in bed
- Less time asleep
- More wakefulness, lower sleep efficiency (especially in second half of the night
- Less slow-wave sleep (min and %)
- More stage 1 and stage 2 sleep
- *Shorter REM latency; less REM sleep*

Carrier et al. 1997. Journal of Sleep Research; Carrier et al. 2001. Psychophysiology. Carrier et al. et al. 2009. Sleep Medicine. Gaudreau et al. 2001. Neurobiology Aging ; Lafortune et al. 2012. PlosOne; Robillard et a;.2016)

NREM sleep EEG
Two electrophysiological markers

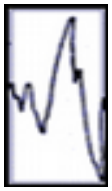


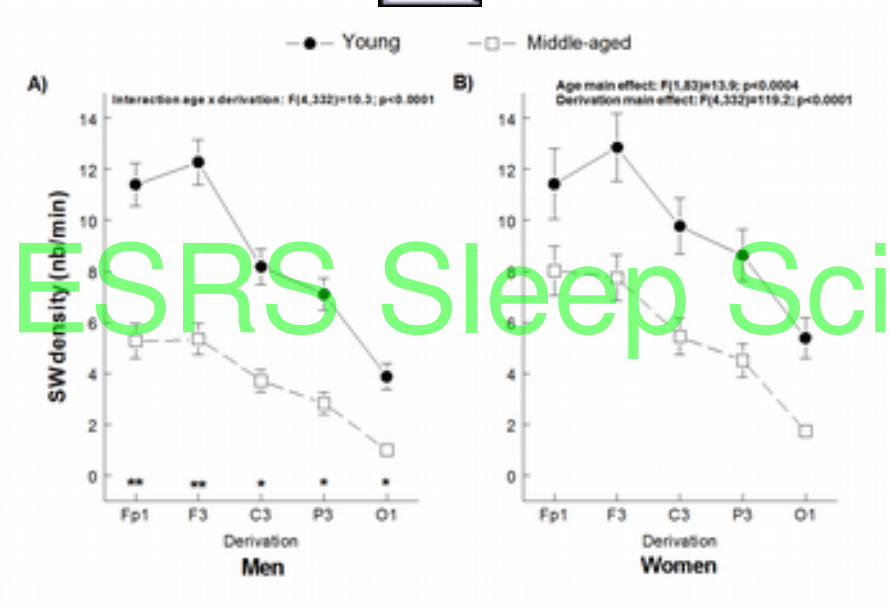
	Spindles		Slow waves
			
Prevalence	+ N2 - N3		+ N3
Frequency	11-15 Hz		< 4 Hz
Duration	> 500 ms		
Amplitude	NA		> 75 µV

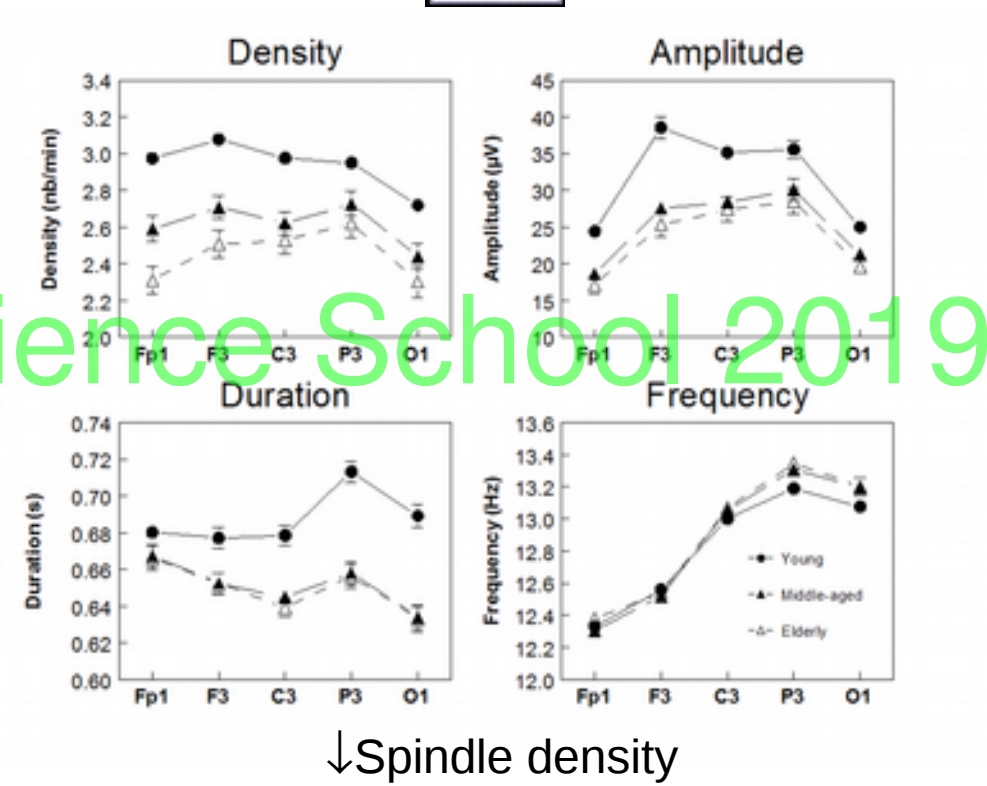
NREM sleep oscillations functions

- Sleep and synaptic homeostasis
- Sleep protection against external stimulations
- Learning, memory, cognition

Important age-related modifications in NREM sleep EEG oscillations





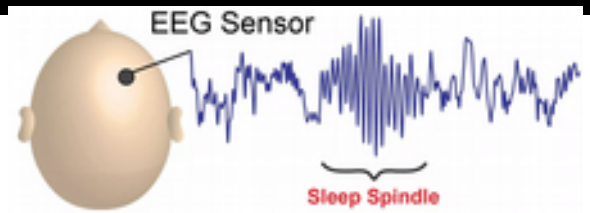


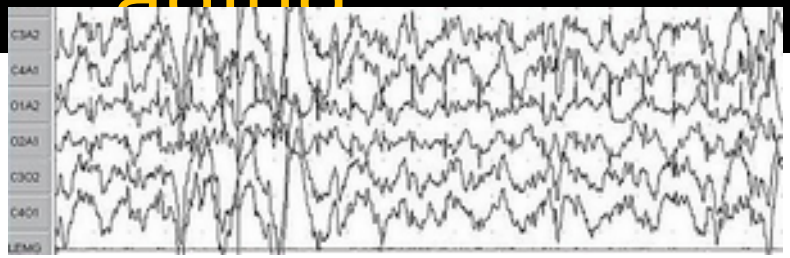
↓SW density
↓SW amplitude
↓SW slope

↓Spindle density
↓ Spindle amplitude
↓Spindle duration

Carrier, Viens et al. 2011. European Journal of Neuroscience
Martin al. (2013). Neurobiology of Aging

Age-related change in NREM sleep is a proxy of cerebral and cognitive health in aging





- May underlie the difficulty that older people have in recuperating and/or maintaining sleep under challenging conditions
- Cognitive performance, sleep-dependent consolidation, amyloid βeta burden, cortical thickness
- Predict the development of dementia in neurodegenerative aging

Latreille et al. 2019, Dube et al., 2015; Fogel et al., 2012; Mander et al., 2016; Mander et al., 2017; Lafortune et al., 2014; Latreille et al., 2015; Fogel et al., 2012; Pace-Schott and Spencer, 2015; Mander et al., 2015; Carrier et al., 2009; Fogel et al., 2012

Sleep become more vulnerable to disturbance with increasing age: Need to take extra care

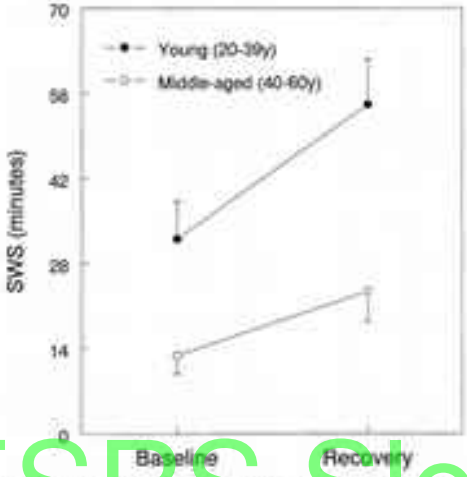
Lower ability to enhance slow-wave sleep after sleep deprivation

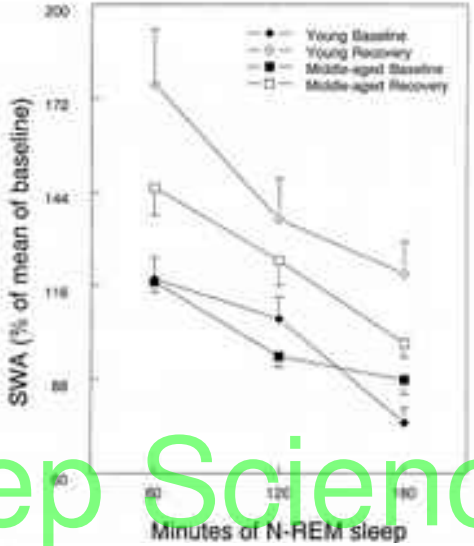
Lower ability to maintain sleep at an abnormal circadian phase (jet lag, shift

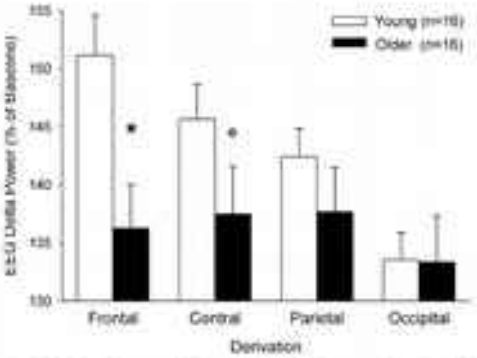
Higher sensitivity to caffeine

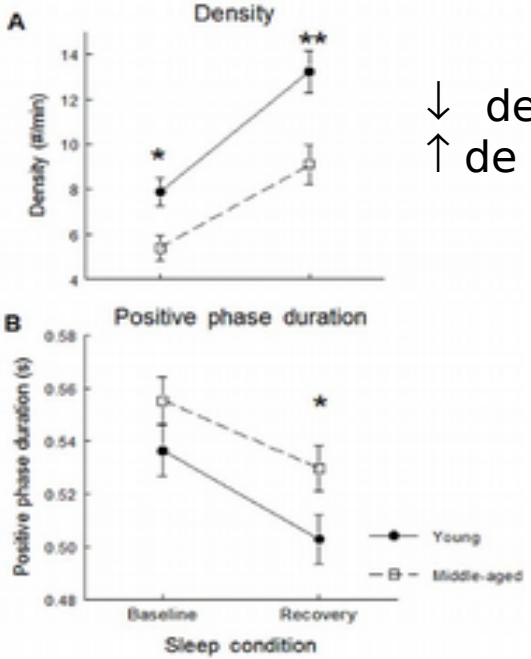
;Carrier et al. 1997. Journal of Sleep Research; Carrier et al. 2001. Psychophysiology. Carrier et al. et al. 2009. Sleep Medicine. Gaudreau et al. 2001. Neurobiology Aging ; Lafortune et al. 2012. PlosOne; Robillard et a;.2016 Munch et al. 2014

Lower ability to increase sleep intensity after sleep loss

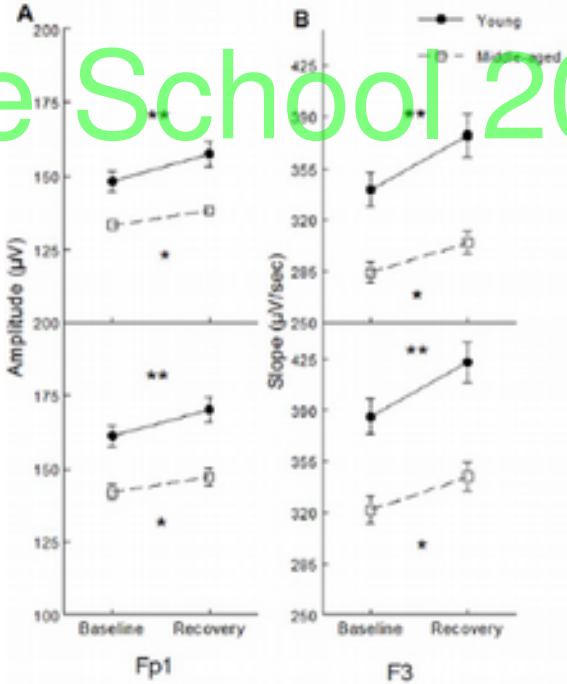






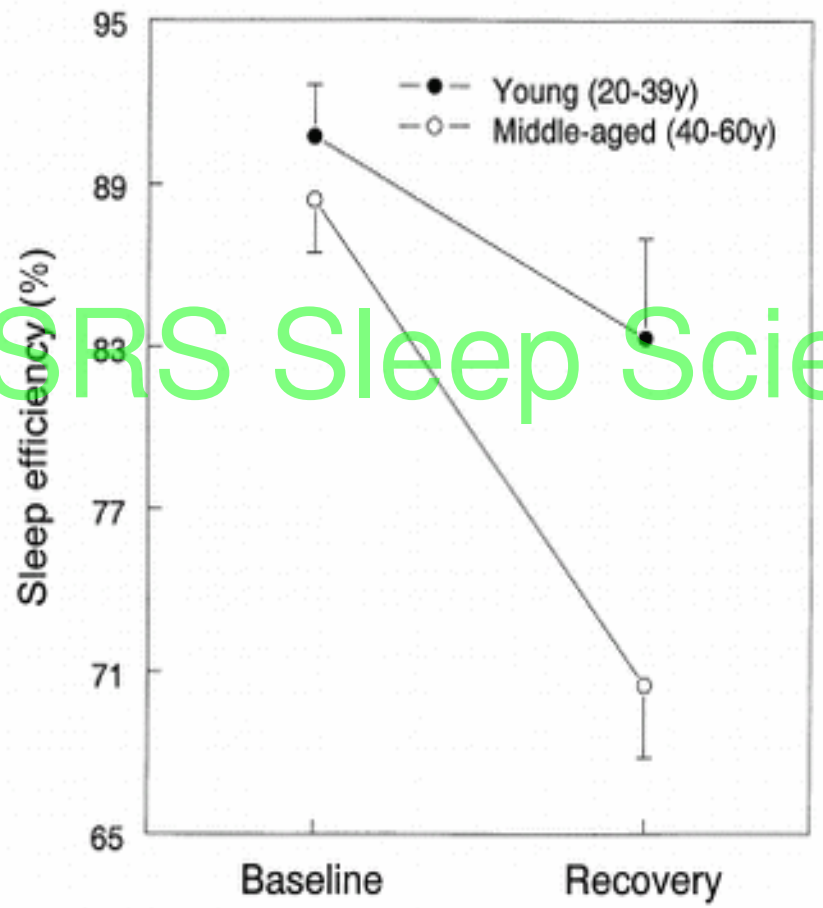


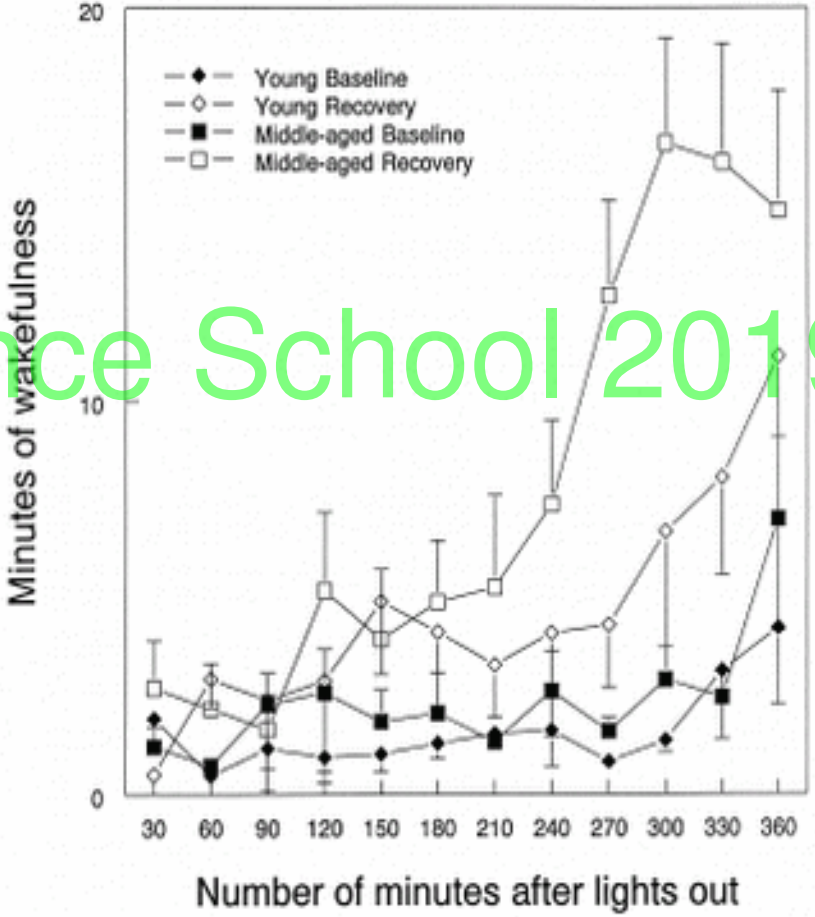
↓ de sensibilité à une
↑ de pression homéostatique



Gaudreau et al. 2001. Neurobiology Aging ;
Munch et al. 2014; Lafortune et al. 2012. PlosOne

Higher sensitivity to sleep at an abnormal circadian phase





Gaudreau et al. 2001. Neurobiology of Aging.
Carrier et al. et al. 2009. Sleep Medicine.

NREM/REM EEG, cognition, normal aging

aps
ASSOCIATION FOR PSYCHOLOGICAL SCIENCE

Sleep, Cognition, and Normal Aging: Integrating a Half Century of Multidisciplinary Research

Perspectives on Psychological Science
2015, Vol. 10(1) 97–137

DOI: 10.1177/1745691614556680
pps.sagepub.com
SAGE

Michael K. Scullin[1,2] and Donald L. Bliwise[2]
[1]Department of Psychology and Neuroscience, Baylor University, and [2]Department of Neurology, Emory University School of Medicine

What is the link between NREM sleep oscillations and general cognitive ability in healthy older subjects ?

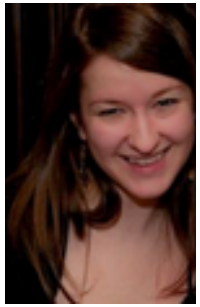
In healthy older subjects (between 50-91 y.o):

↑ Spindle density is associated to ↑ performance:

- Declarative memory (Rey verbal learning task)
- Attention (Bell test and Continuous Performance tasks)
- Verbal fluency

↑ SW density is associated to ↑ performance :

- Verbal fluency



Lafortune et al. (2013). Journal of Sleep Research.

NREM/REM EEG :
Proxy of neurodegenrescence

Hindawi Publishing Corporation
Neural Plasticity
Volume 2016, Article ID 8376408, 10 pages
http://dx.doi.org/10.1155/2016/8376408

Research Article

Parietal Fast Sleep Spindle Density Decrease in Alzheimer's Disease and Amnesic Mild Cognitive Impairment

Maurizio Gorgoni,[1] Giulia Lauri,[1] Ilaria Truglia,[1] Susanna Cordone,[2] Simone Sarasso,[3] Serena Scarpelli,[1] Anastasia Mangiaruga,[1] Aurora D'Atri,[1] Daniela Tempesta,[4] Michele Ferrara,[5] Camillo Marra,[6] Paolo Maria Rossini,[6,7] and Luigi De Gennaro[1]

Biological Psychology
Contents lists available at ScienceDirect
journal homepage: www.elsevier.com/locate/biopsycho

Changes in sleep theta rhythm are related to episodic memory impairment in early Alzheimer's disease

Pascal Hot, Géraldine Bauchs, Françoise Bertran, Pierre Denise, Béatrice Desgranges, Patrice Clochon, Francis Eustache

Neurology/Medicine

Quantitative EEG of Rapid-Eye-Movement Sleep: A Marker of Amnestic Mild Cognitive Impairment

Clinical EEG and Neuroscience
2016, Vol. 47(2) 134–141
© EEG and Clinical Neuroscience Society (ECNS) 2015
SAGE

Pauline Brayet[1,2], Dominique Petit[1,3], Birgit Frauscher[4], Jean-François Gagnon[1,2], Nadia Gosselin[1,5], Katia Gagnon[1,2], Isabelle Rouleau[2,6], and Jacques Montplaisir[1,3]

Non-REM Sleep Characteristics Predict Early Cognitive Impairment in an Aging Population

Jacques Taillard, Patricia Sagaspe, Christian Berthomier, Marie Brandewinder, Hélène Amieva, Jean-François Dartigues, Muriel Rainchey, Sandrine Harston, Jean-Arthur Micoulaud-Franchi and Pierre Philip

BRAIN
A JOURNAL OF NEUROLOGY
REPORT

Slow wave sleep disruption increases cerebrospinal fluid amyloid-β levels

Yo-El S. Ju, Sharon J. Ooms, Courtney Sutphen, Shannon L. Macauley, Margaret A. Zangrilli, Gina Jerome, Anne M. Fagan, Emmanuel Mignot, John M. Zempel, Jurgen A.H.R. Claassen and David M. Holtzman

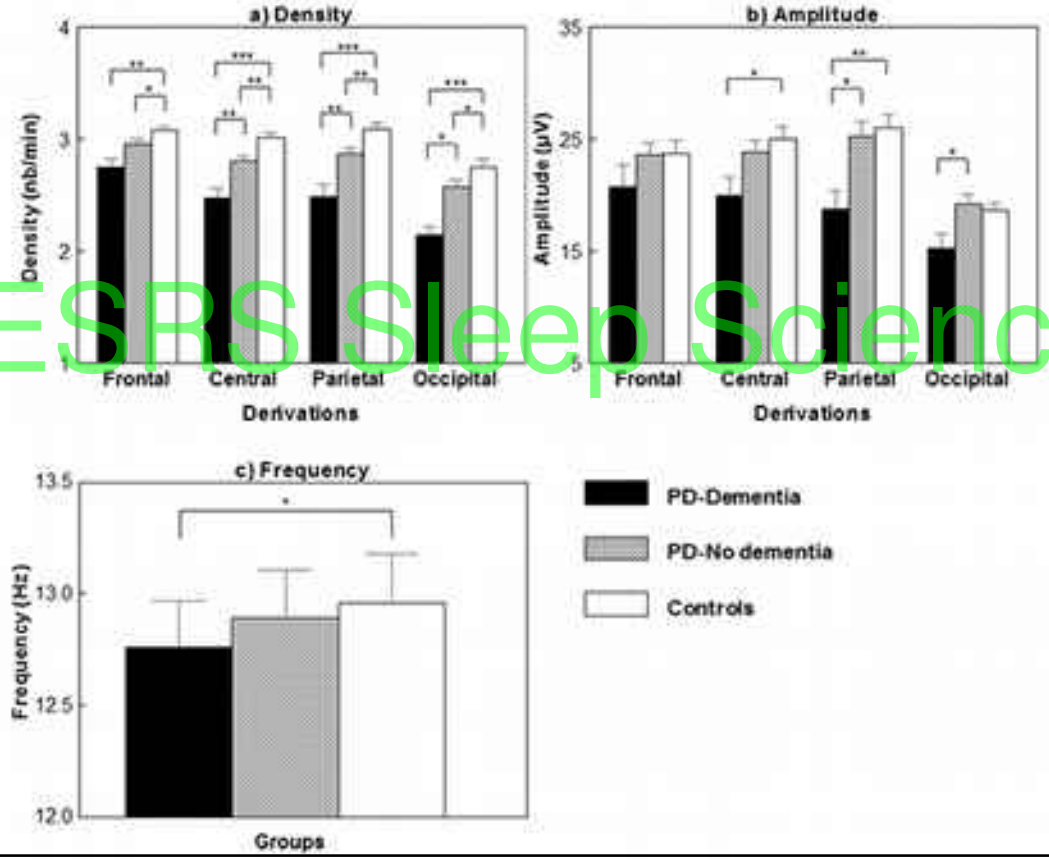
Neurobiology of Disease

Sleep as a Potential Biomarker of Tau and β-Amyloid Burden in the Human Brain

Joseph R. Winer, Bryce A. Mander, Randolph I. Helfrich, Anne Maass, Theresa M. Harrison, Suzanne L. Baker, Robert T. Knight, William J. Jagust and Matthew P. Walker

Do spindles in Parkinson Disease predict the development of dementia?

↓ Spindles in patients with PD (Christensen et al. 2014)



<u>Baseline PSG</u>
68 non-demented PD patients
40 healthy individuals

<u>At follow-up (4.5 years)</u>
18 PD patients developed dementia
50 remained dementia free

Spindles at baseline are associated with likelihood of developing dementia at follow-up (4.5 later)

V.Latreille J-F Gagnon

Latreille et al. Neurobiology of Aging (2015).

REM sleep: a window on cholinergic transmission in Parkinson

- Cholinergic degeneration may be especially key to early cognitive impairment in PD (Kehagia *et al.*, 2010; Gratwicke *et al.*, 2015; Bohnen and Albin, 2011; Hall *et al.*, 2014; Liu *et al.*, 2015).

- N-REM sleep: cholinergic activity is nearly absent

- REM sleep differs from wakefulness: sustain activity mainly cholinergic, with very little input from other neurotransmitter systems (i.e., noradrenaline, serotonin, and dopamine).

- REM sleep is the ideal state to investigate cholinergic transmission integrity in PD.

doi:10.1093/brain/aww018 BRAIN 2016: 139; 1189–1199 | 1189

BRAIN
A JOURNAL OF NEUROLOGY

Electroencephalographic prodromal markers of dementia across conscious states in Parkinson's disease

Véronique Latreille,[1,2] Julie Carrier,[1,2] Benjamin Gaudet-Fex,[1,2] Jessica Rodrigues-Brazète,[1,2] Michel Panisset,[3] Sylvain Chouinard,[3] Ronald B. Postuma[1,4] and Jean-François Gagnon[1,5]

V.Latreille
J-F Gagnon

REM sleep EEG slowing predicts dementia in PD

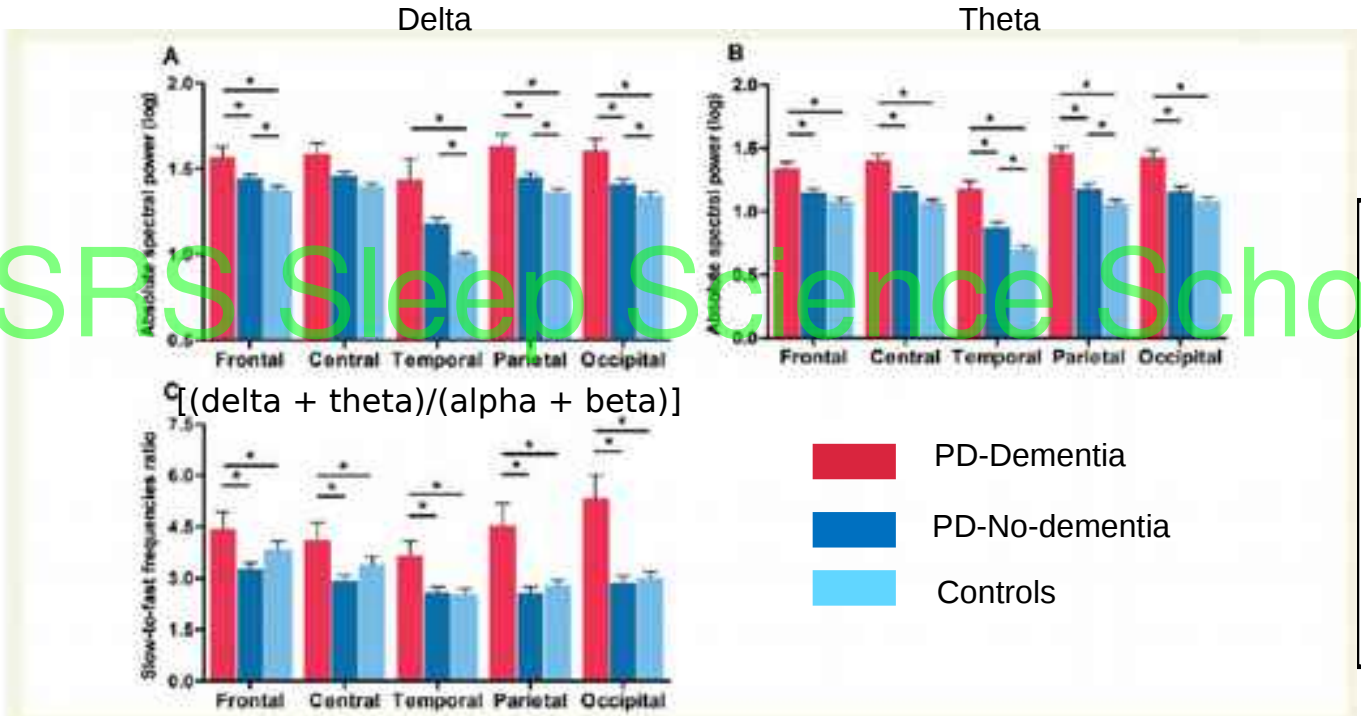


Figure 1 PDD patients showed higher REM sleep EEG slowing. Absolute spectral power in the delta (A) and theta (B) frequency bands, and slow-to-fast frequencies ratio (C) for each derivation in PDD patients (red), PDnD patients (dark blue), and controls (light blue). Post hoc analyses: *$P < 0.05$. Results are expressed as mean (± standard error of the mean).

Baseline PSG
68 non-demented PD patients
40 healthy individuals

At follow-up (4.5 years)
18 PD patients developed dementia
50 remained dementia free

Latreille et al. Brain (2016).

V.Latreille
J-F Gagnon

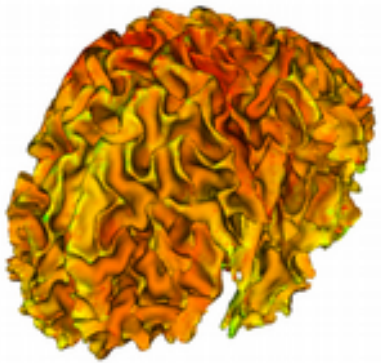
Are age-related modifications in NREM EEG oscillations associated with anatomical and functional changes in the brain?

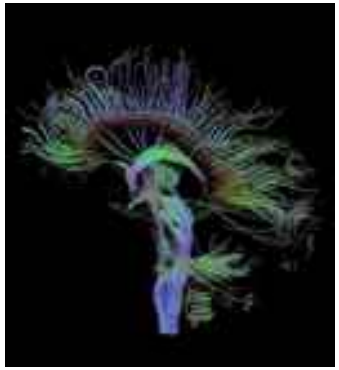
Multimodal approach using

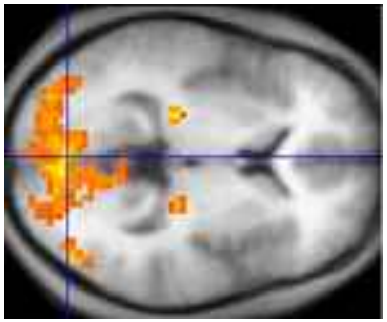
MRI, fMRI-EEG, MEG-EEG

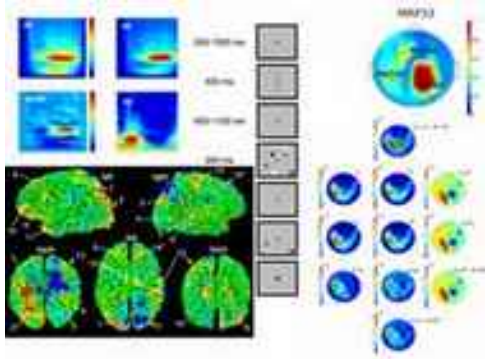
⇓

May underlie age-related changes in brain plasticity and cognition



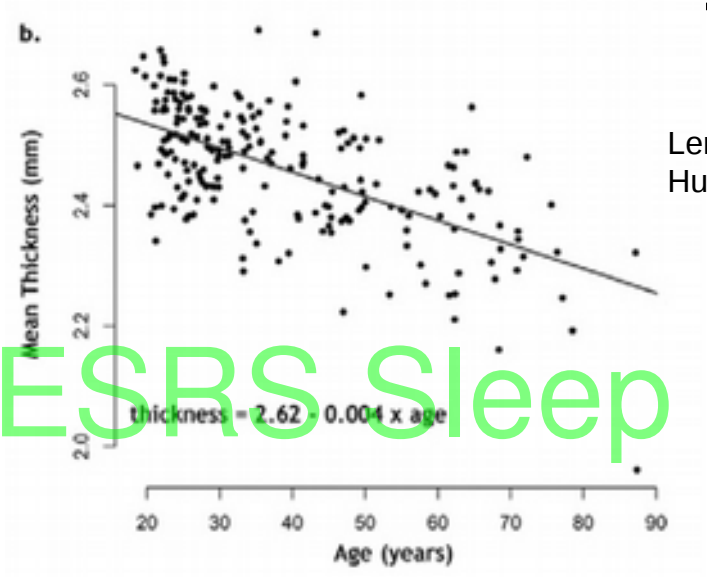




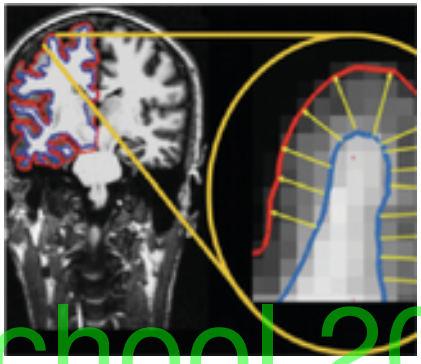


Are age-related changes in NREM EEG oscillations associated with cortical grey matter ?

changes in grey matter

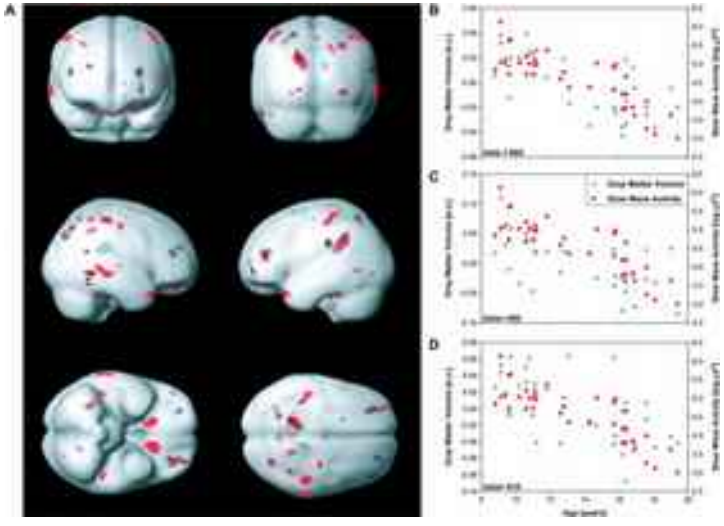


Lemaître et al., 2012 –
Hutton et al., 2009 -



Distance (mm) between cortical layers

- External: cerebrospinal fluid
- Internal:white matter



Bushmann et a. 2011

Marjolaine Lafortune
Jonathan Dubé

Does cortical thickness explain age-related change in slow waves?

Mediation model

$b_{\text{frontal sw density}} = -.25$; $p < 0.001$

$b_{\text{frontal sw amplitude}} = -0.09$; $p < 0.001$

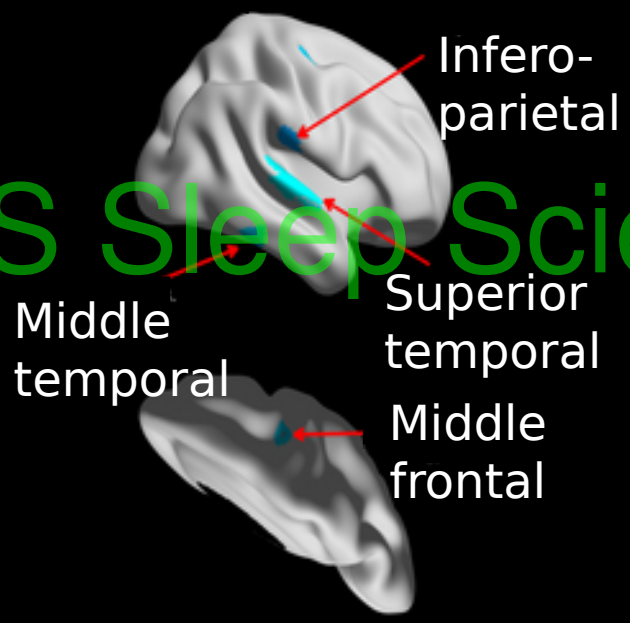
Step 3 : Indirect effect of age (through cortical thickness):

Preacher & Hayes, 2013

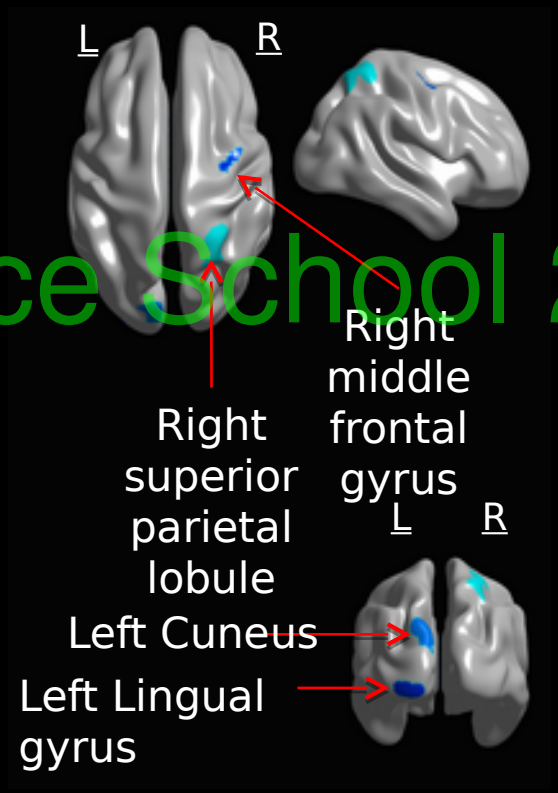
X Dubé et al. J Neurosci. (2015)

Cortical thickness is associated to SW density and SW amplitude

SW density (nb/min)



SW amplitude (µV)



Most cortical regions associated to SW show lower cortical thickness in older subjects

SW density	SW amplitude
Middle frontal	Middle frontal
Middle temporal	Superior parietal lobule
Infero-temporal	Cuneus
Superior temporal	Lingual

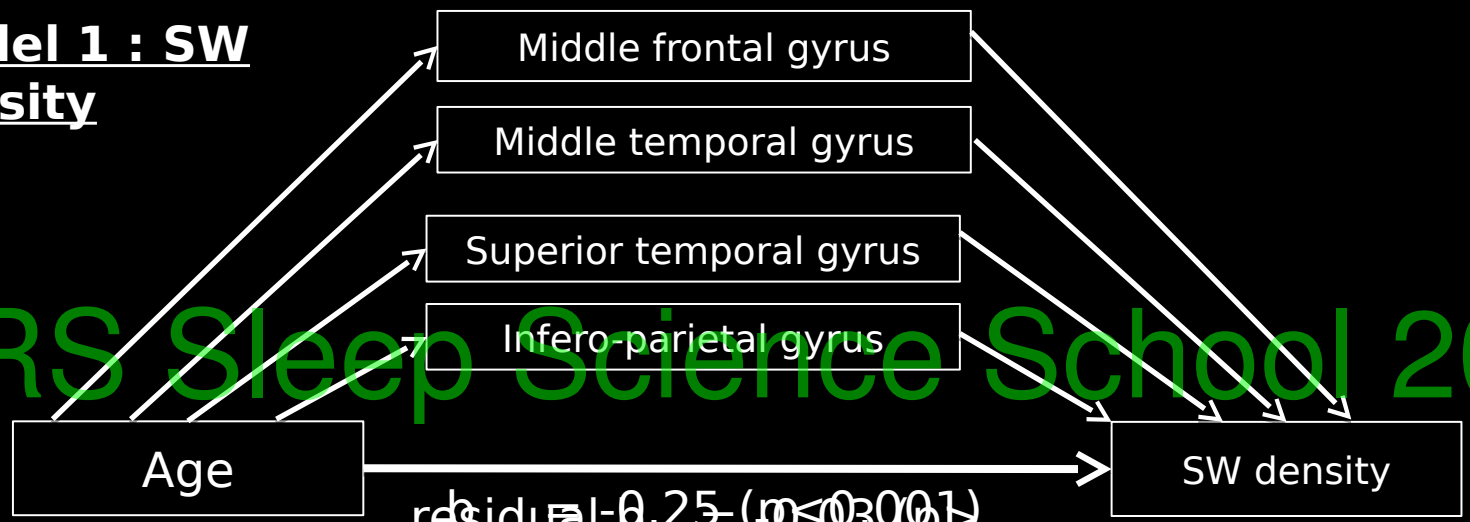
Integrative model

Parallel mediation analysis

→ $p<0.05$

→ $p<0.05$ (parallel model)

Model 1 : SW density



$b_{age} = -0.25$ ($p<0.001$)

residual $b_{age} = -0.03$ ($p>0.9$)

$b_{age} = -0.25$, $p< 0.001$

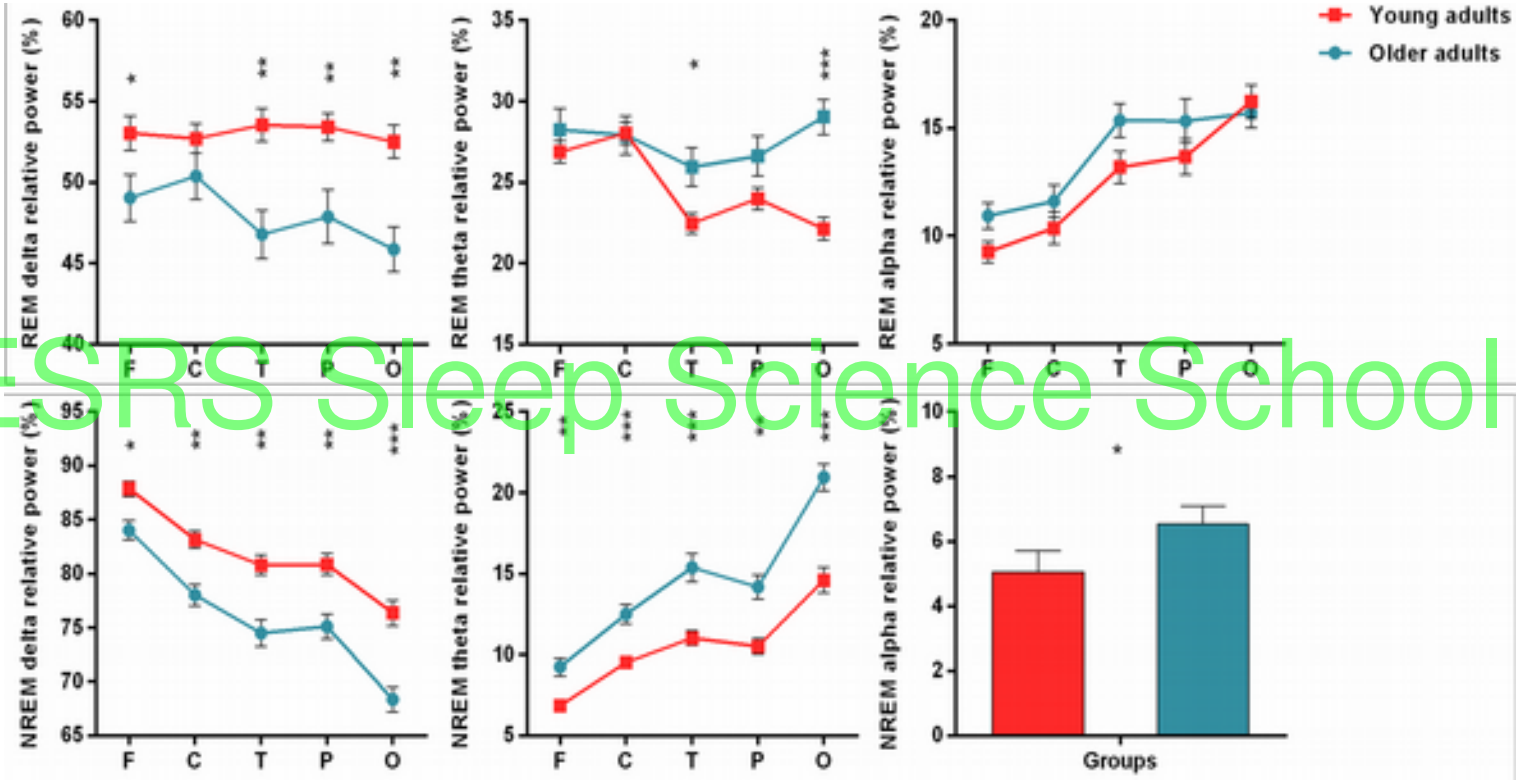
residual $b_{age} = -.05$, $p = 0.005$

Conclusions

Thinning in a network of cortical regions involved in SW generation and propagation, but also in cognitive functions, explained the age-related decrease in SW density and amplitude.

Dubé et al. (2015) Journal of Neuroscience

Age-related changes in relative spectral power in REM and NREM sleep



Latreille et al. (2019). Neurobiology of Aging

After controlling for age, spectal power is associated with cortical thickness in both REM and non-REM sleep

REM sleep
Delta: Central
Left superior frontal gyrus
Left lateral orbitofrontal cortex
Right rostral anterior cingulate cortex
Delta: Temporal
Left superior frontal gyrus
Delta: Parietal
Left/right superior frontal gyrus
Right superior temporal gyrus
Delta: Occipital
Left superior frontal gyrus

NREM sleep
Delta: Central
Left medial orbitofrontal cortex
Theta: Occipital
Right lateral occipital cortex

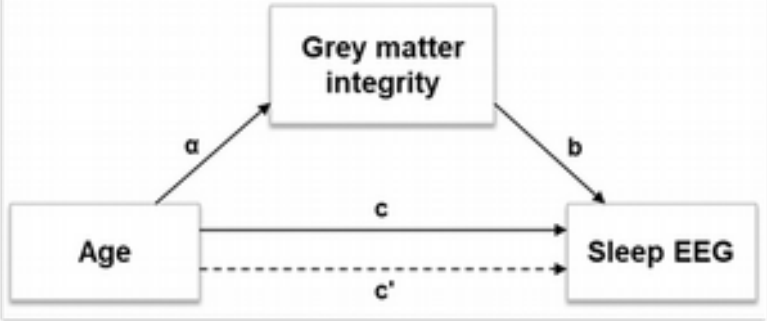
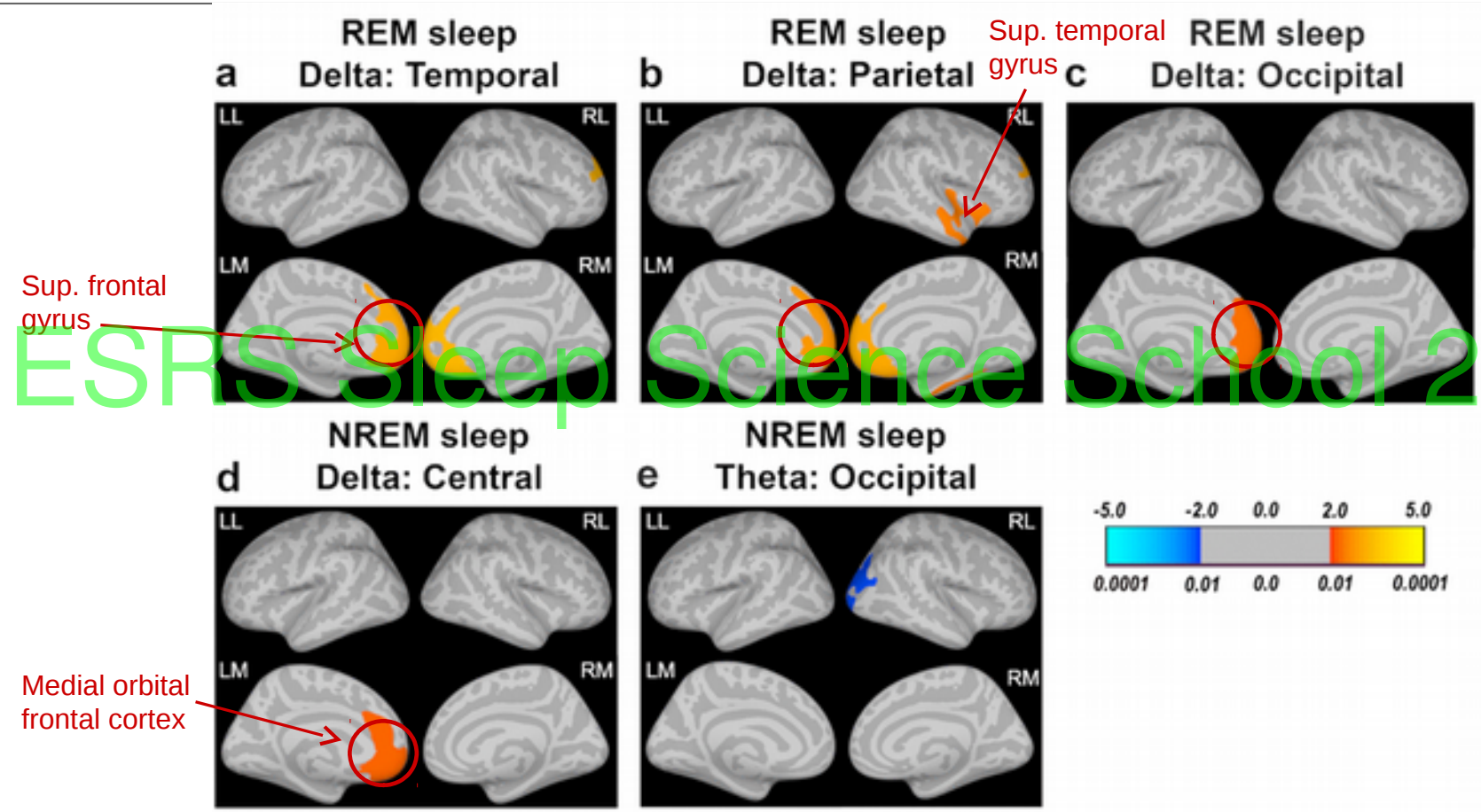


Fig 1. Mediation model illustrating how cortical thickness may mediate the relationship between age and sleep EEG.

Latreille et al. (2019). Neurobiology of Aging

Cortical thickness explains age-related changes in REM and NREM sleep



Latreille et al. (2019). Neurobiology of Aging)

Are age-related changes in REM sleep associated to grey matter?

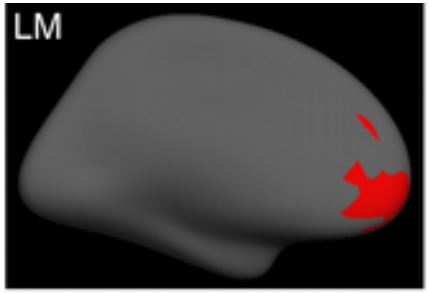


Fig 4. Conjunction maps of delta power correlates across REM and NREM sleep.

Thinning of the left superior frontal gyrus (spreading to the anterior cingulate and medial orbitofrontal cortices) drives EEG desynchrony during both REM and NREM sleep with aging

Common mechanisms for both REM and NREM

Medial frontal and cingulate cortices: major hubs of the human brain, in synchronizing neuronal assemblies during sleep

Latreille et al. (2019). Neurobiology of Aging.

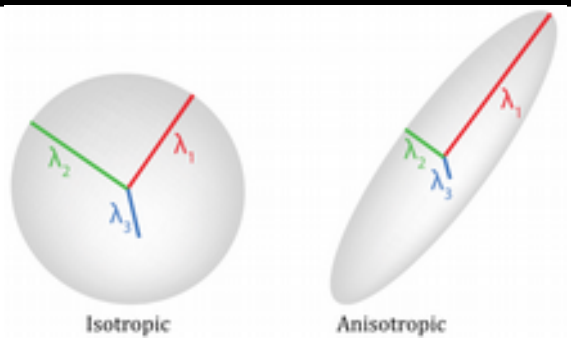
Are age-related changes in NREM EEG oscillations associated with white matter integrity ?

Diffusion tensor imaging (*DTI*): water diffusion in each voxel (tensor)

Anisotropy of the diffusion=one preferential direction

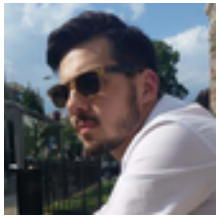
Tract-Based Spatial Statistics:

4 metrics: radial diffusivity (**RD**), axial diffusivity (**AD**), mean diffusivity (**MD**), fractional anisotropy (**FA**)



In the young: ↑ sigma spectral power and ↑ spindle density is associated with higher AD (Piantoni et al 2013)

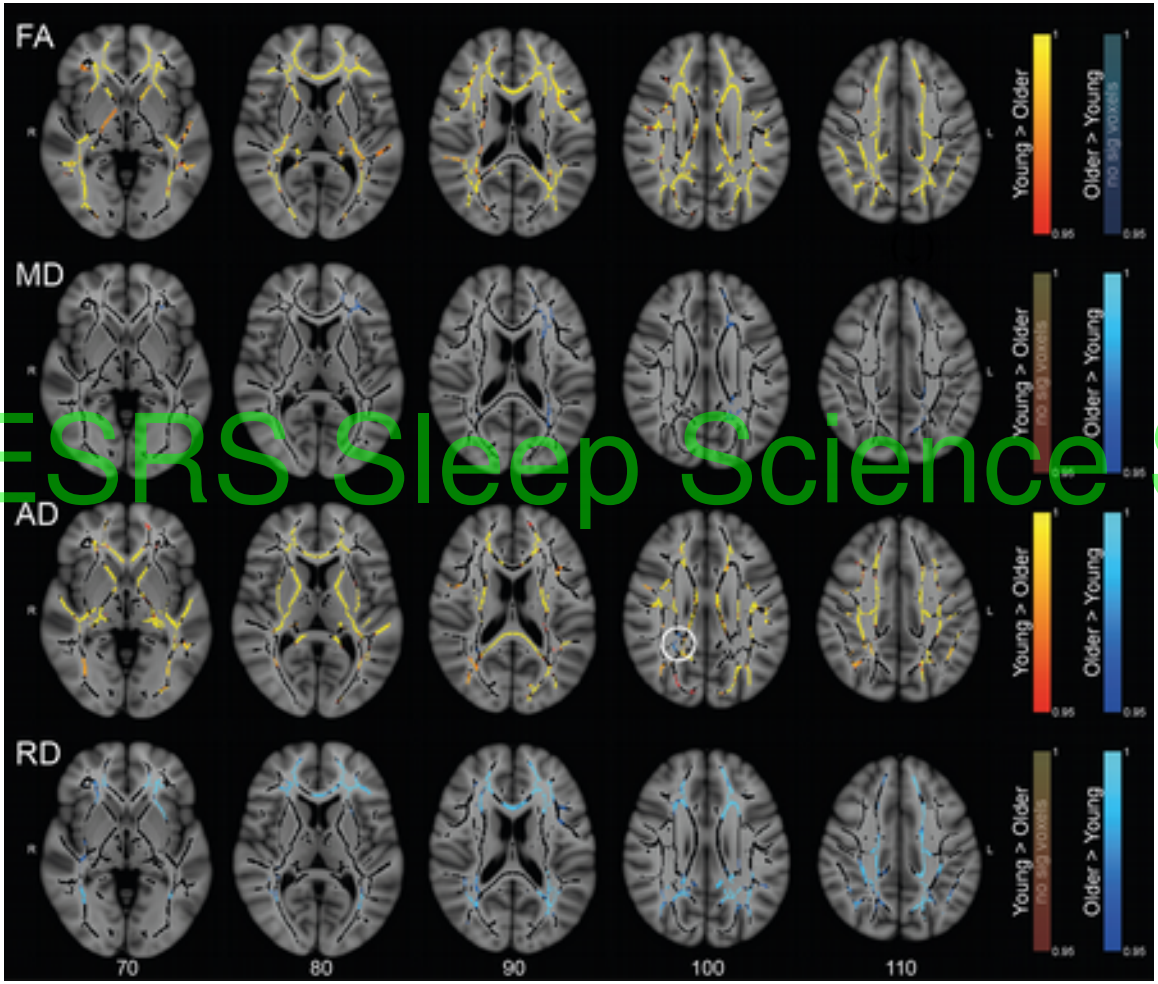
White Matter older adults moderates the benefit of sleep spindles on motor memory consolidation (Mander et al. 2018)



Pierre-Olivier Gaudreault

Samuel Deslaurier-Gauthier, Ph.D.

Older individuals show lower white matter integrity than young individuals



FA (↓)
Forceps Minor
Inferior fronto-occipital fasciculus (IFOF)

MD (↑)
Left anterior thalamic radiation
Minor Forceps
IFOF
Left Uncinate fasciculus
Part of cingular

AD (↓)
Minor Forceps
Right Corticospinal track
Major Forceps
IFOF

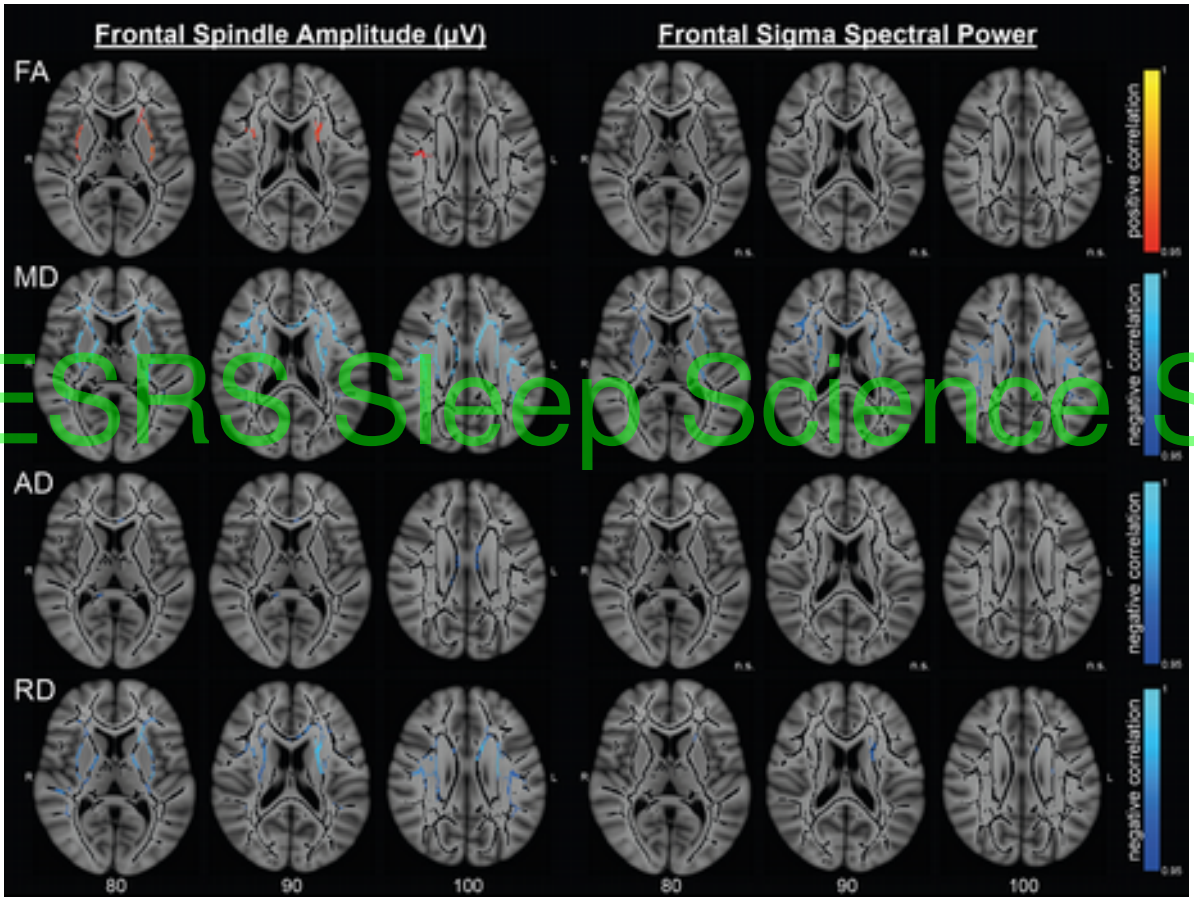
RD (↑)
Anterior thalamic radiation
Forceps Minor
IFOF
SLF
Right Inferior longitudinal fasciculus
Part cingular

Gaudreault et al. SLEEP (2018)

Are frontal and central spindle characteristics associated with white matter integrity after controlling for age?

No mediation effect:
White matter does not explain lower spindles in older individuals

Frontal spindle amplitude and sigma spectral power are associated to WM diffusion metrics only in the young individuals



→ <u>Frontal spindle amplitude</u>

FA (+)

Inferior fronto-occipital fasciculus (IFOF)
Superior Longitudinal fasciculus (SLF)
Uncinate fasciculus
Anterior thalamic radiation (left)
Corticospinal track (right)

<u>MD (-)</u>

Forceps Minor
Superior Longitudinal fasciculus (SLF)

<u>AD (-)</u>

Forceps Minor
Forceps Major

<u>RD (-)</u>

Inferior fronto-occipital fasciculus (IFOF)
Superior Longitudinal fasciculus (SLF)
Uncinate fasciculus gauche
Anterior thalamic radiation (left)
Corticsopinal track (right)

<u>Frontal Sigma</u>

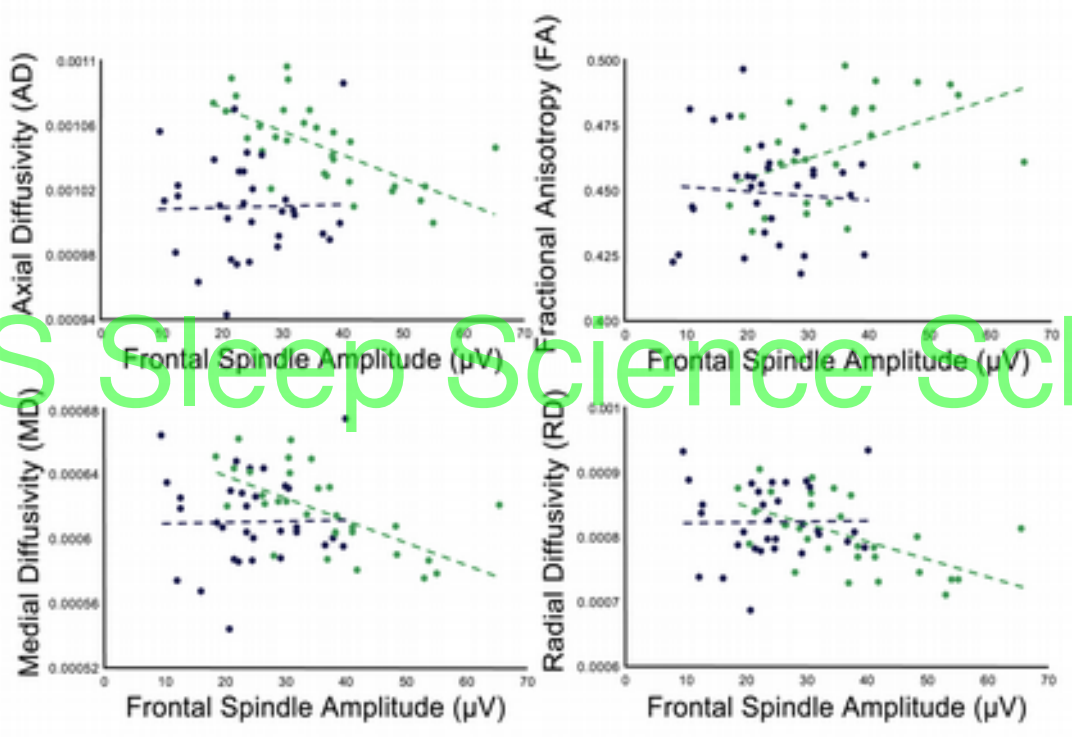
<u>MD (-)</u>

Superior Longitudinal fasciculus (SLF) bilatéral

<u>RD (-)</u>

Anterior thalamic radiation (left)
Inferior fronto-occipital

Moderation analyses: the association between white matter and sleep spindles differs in young and older individuals



Diffusion metrics explained between 14% and 39% of SS amplitude and sigma power variance in the young subjects only

Gaudreault et al. SLEEP (2018)

To connect or not connect during sleep: this is the question!

Cognitive and mental functions emerges from **the brain's complex networks.**

Most conclusions on functional connectivity during human sleep come from studies **in young individuals**.

Age-related change in functional connectivity during sleep may very well underlying **cerebral and cognitive health in aging**

fMRI functional connectivity (FC) during NREM

EEG/fMRI studies in the young: NREM sleep induces important modifications in cortical and sub-cortical networks underlying sensory awareness, information transfer, memory consolidation and executive control.

Fading of consciousness: greater local cortical FC, but a breakdown of long range cortico-cortical FC during NREM sleep with the descent from wakefulness to SWS sleep.

Horovitz et al. 2008; Samann et al. 2011; Wu et al. 2012; Spoormaker et al .2010,2011,2012; Tagliazucchi et al. 2013; Boly et al. 2012; Lee et al. 2012

Our fMRI study

NREM sleep in older individuals: Important modifications including lighter sleep, lower slow-waves and spindle density/amplitude.

Objective: to investigate changes in fMRI FC that occur during NREM sleep in aging.

Hypothesis: Older individuals will show a lower breakdown of FC during NREM sleep than young participants

Methodology (fMRI)

Participants:

Young (20-30 y) = 16(8F); mean= 23.3±3.3

Older (52-69 y) = 14(9F); mean = 59.5±5.9

Data acquisition (90 minutes) after a 26-hour sleep deprivation

EEG (32-electrode cap)

Scanner gradient EEG artifacts: Adaptive subtraction; Residual artifacts removed usinICA).

Ballistocardiographic artifacts: Constrained cICA (Leclercq et al., 2009).

Sleep scoring

fMRI (BASC-GLM)

Bootstrap analysis of stable clusters (BASC): (Bellec et al., 2010): identify brain regions that consistently exhibited similar spontaneous activity in individual subjects, and were spatially stable across both young and older participants.

Cerebral functional connectivity analyses: Standard correlation measures based on Bold signal fluctuations

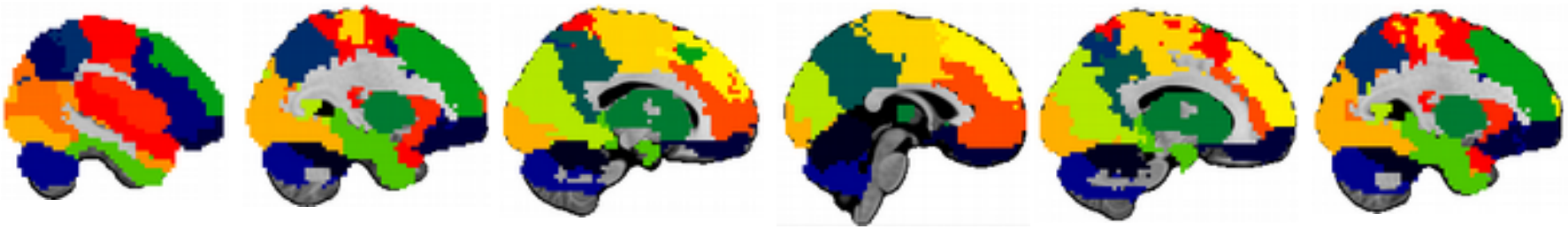
Nicolas Martin, Ph.D.

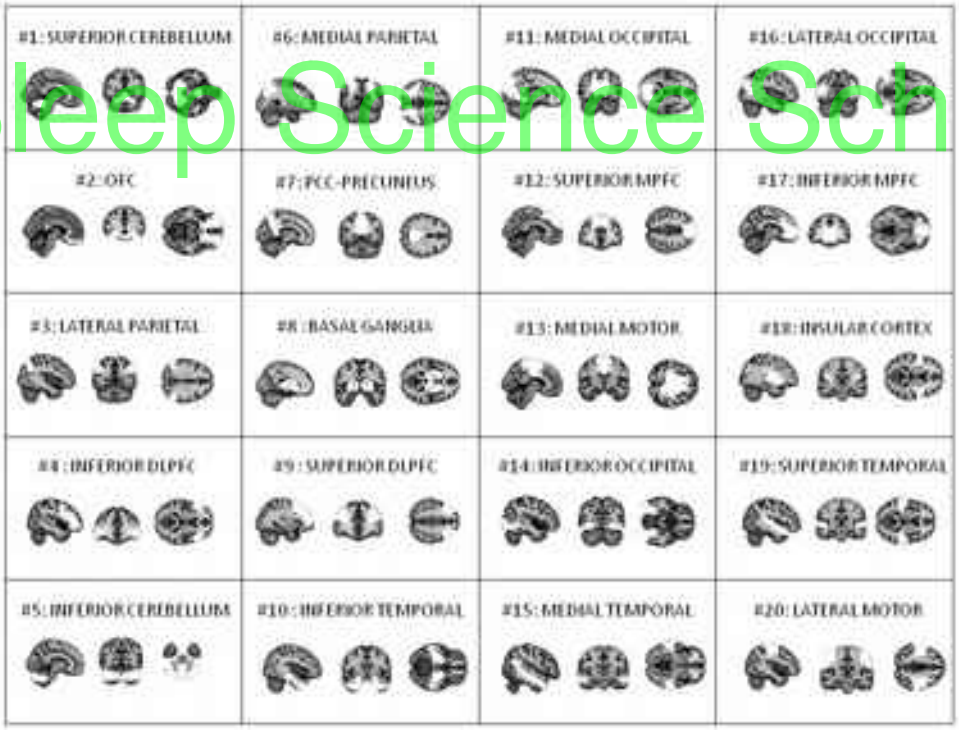
Pierre Bellec, Ph.D

Pierre Orban, Ph.D.

Véronique Daneault, Ph.D.

Data-driven parcellization 20 regions



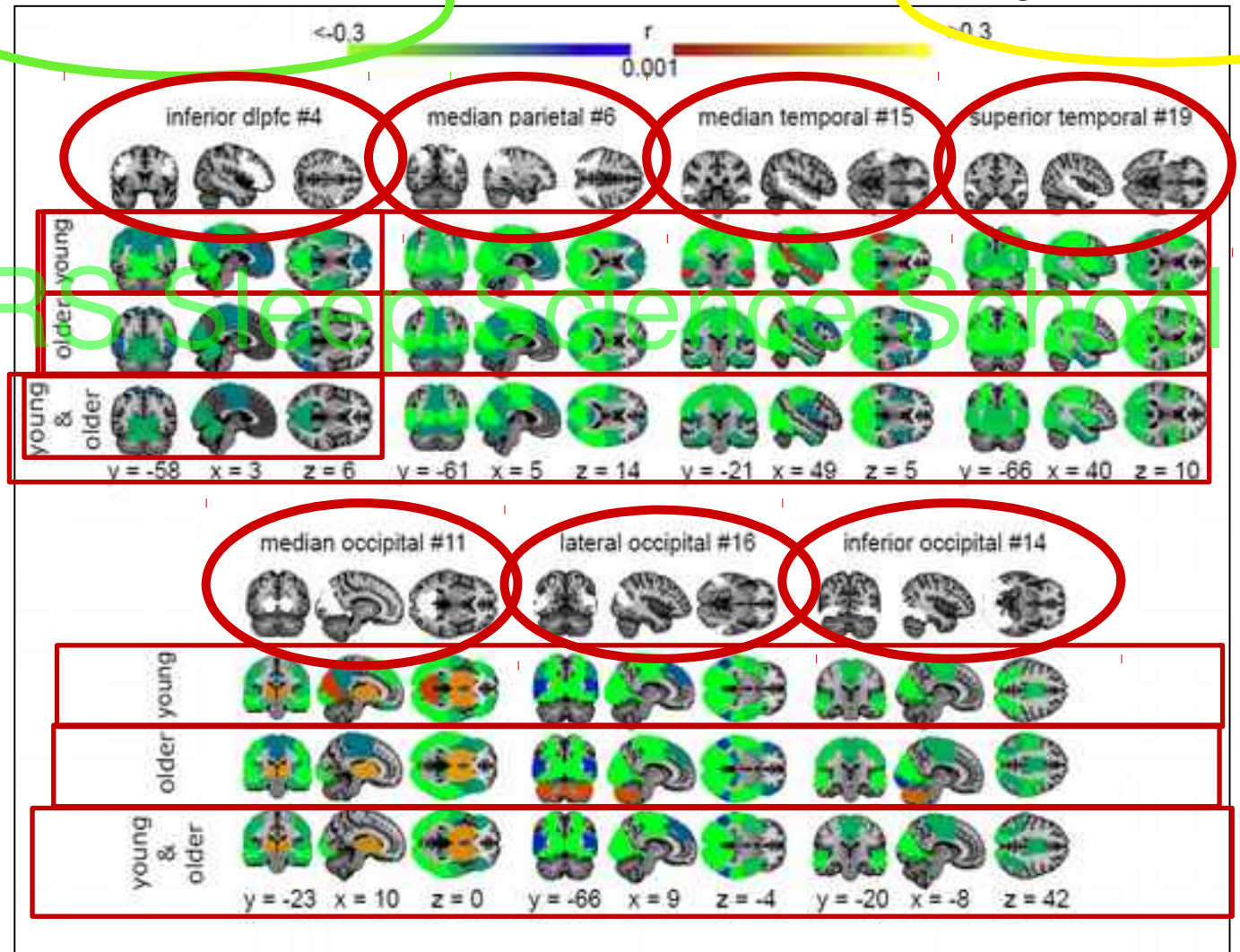


20 homogeneous regions in terms of fluctuations of the BOLD signal

NREM2 vs Wake
Similar effects in young and older

Lower FC in NREM2

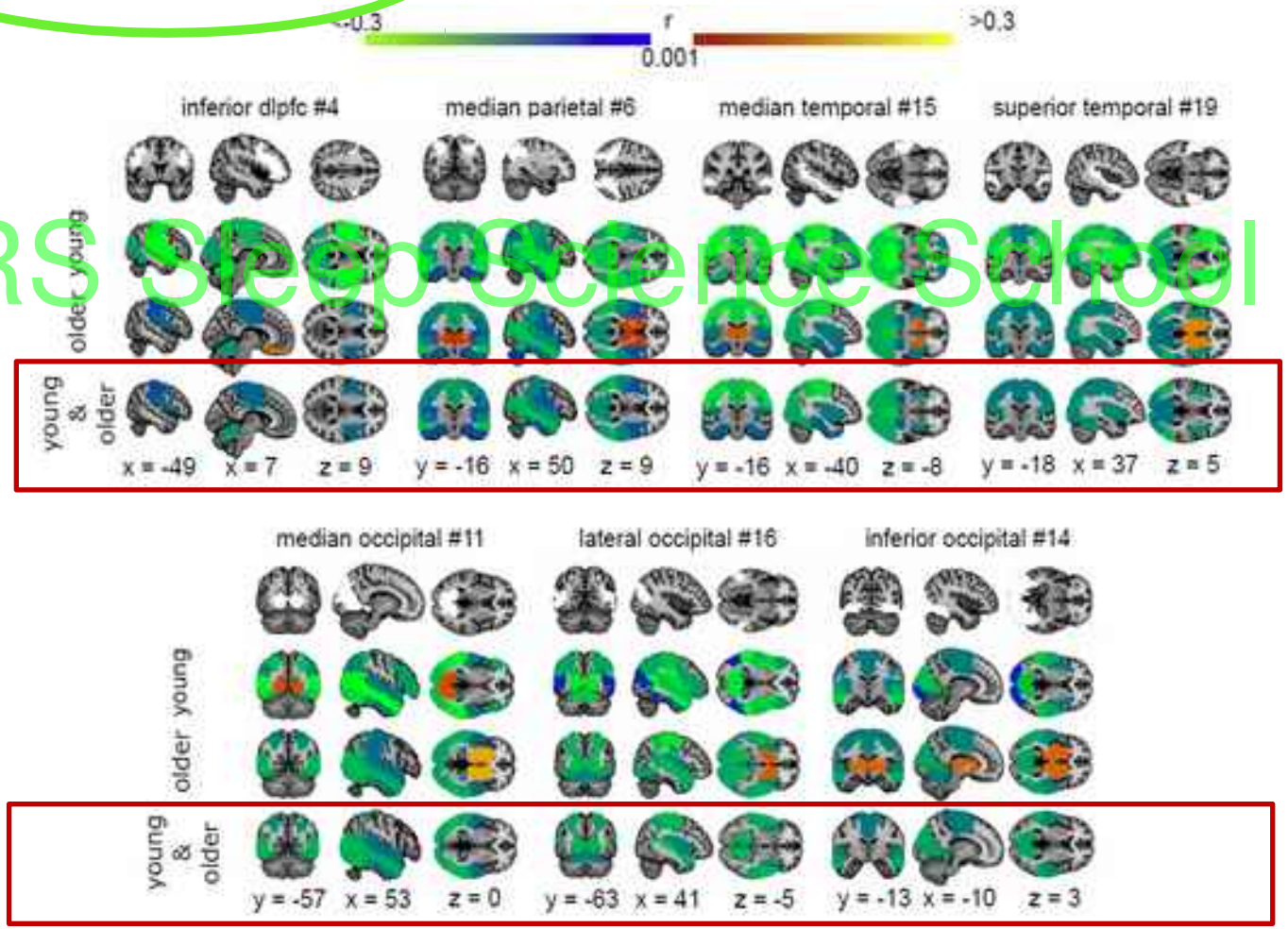
Higher FC in NREM2



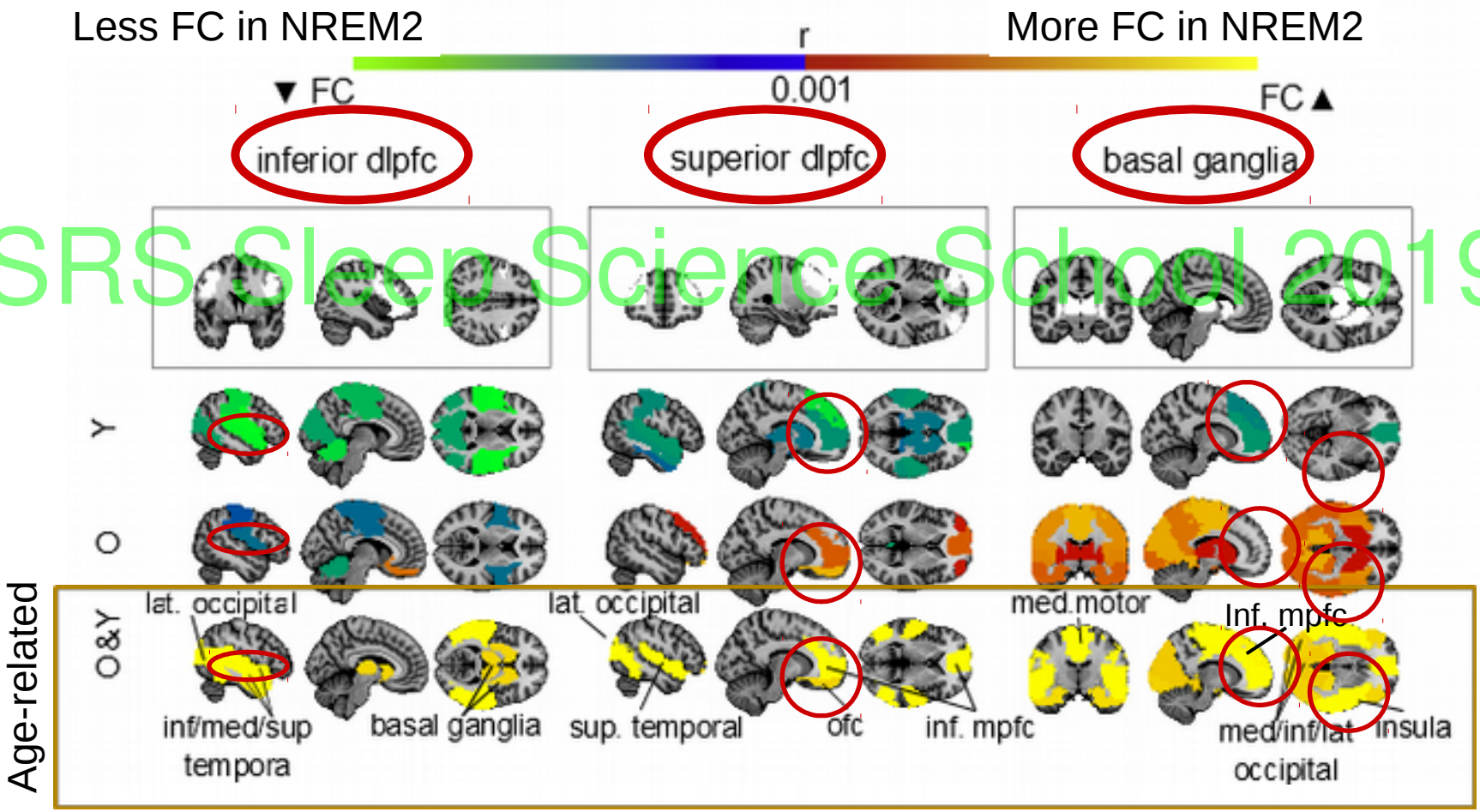
NREM2 vs NREM1
Similar effects in young and older

Lower FC in NREM2

Higher FC in NREM2



NREM2vsNREM1
Sronger FC ⇓ in young and ⇑ FC in older



Conclusions (1)

- **Young and older individuals:** very similar decreases in cortico-cortical fMRI FC between wakefulness and NREM2 and globally, between NREM1 and NREM2.

- **Age-related difference in FC:** between NREM2 and NREM1 in **specific** brain networks (16%)

- **Older subjects:** shallower ⇓ fMRI FC or ⇑ FC between NREM2 and NREM1 between networks underlying sensory awareness, information transfer, memory consolidation , executive control

Age related changes in EEG coherence during sleep

- How two EEG sensors (brain regions) show similar neuronal oscillatory activity (frequency specific).

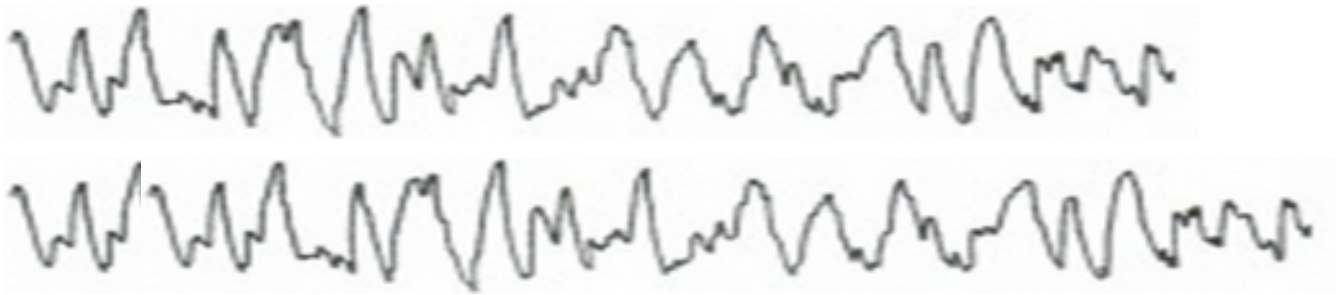
- Complete night study
- All sleep stages
- More ecological environment

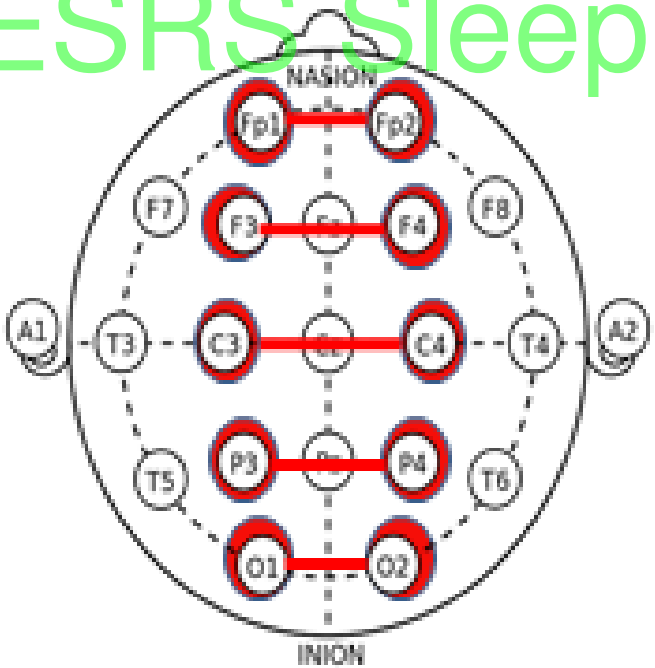
Maude Bouchard,
B.Sc., Ph.D. student

Jean-Marc Lina,
Ph.D., ETS, CÉAMS

Bouchard et al. (2019). SLEEP.

Imaginary EEG coherence

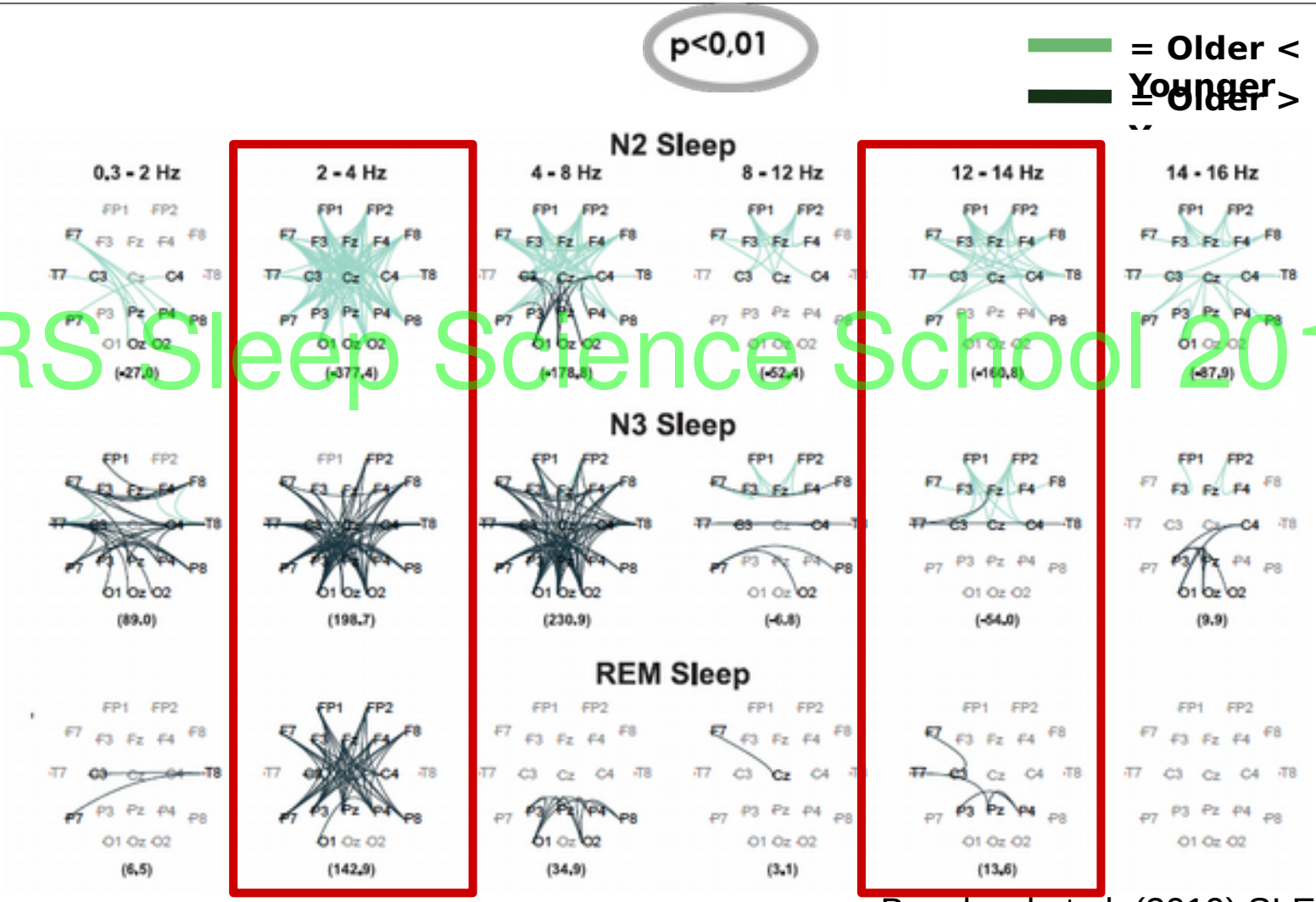




- **The "strength" of functional interactions between two cortical areas in different frequency bands (delta, theta, sigma, alpha, beta).**
- **Removal of 0 lag contribution**

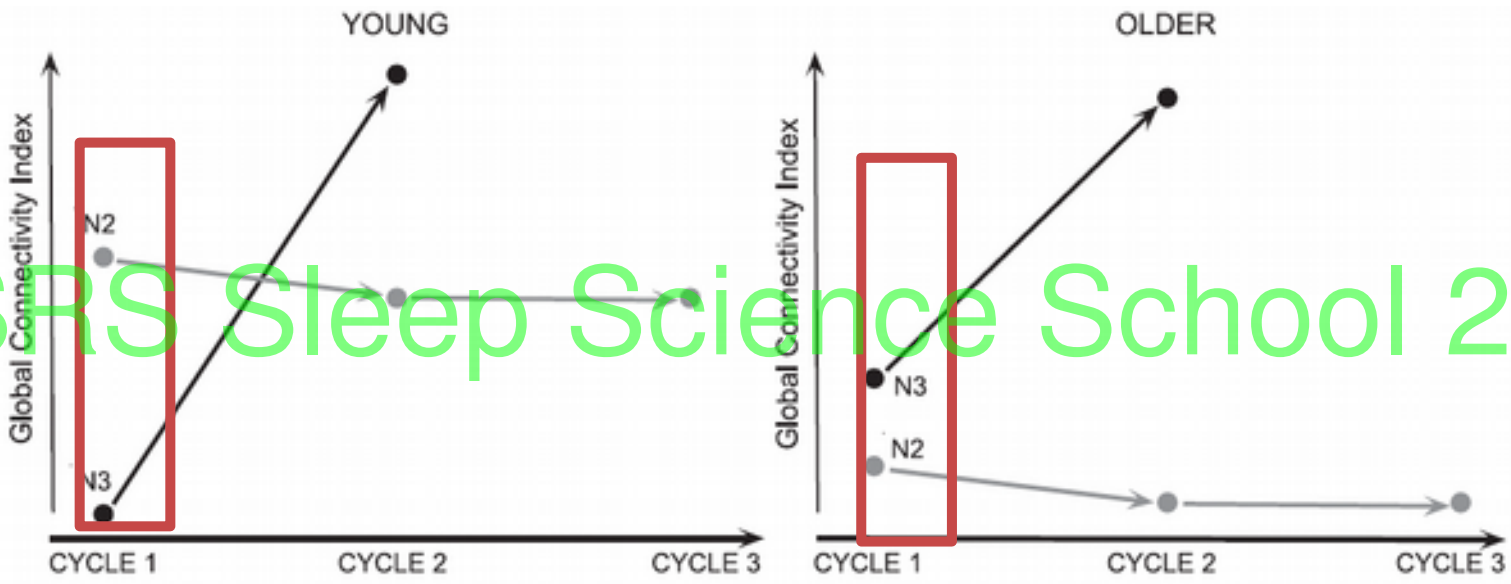
Castro et al., 2014

EEG coherence differences between older and younger individuals



Bouchard et al. (2019) SLEEP

Changes in EEG coherence (2-4 Hz) across the night



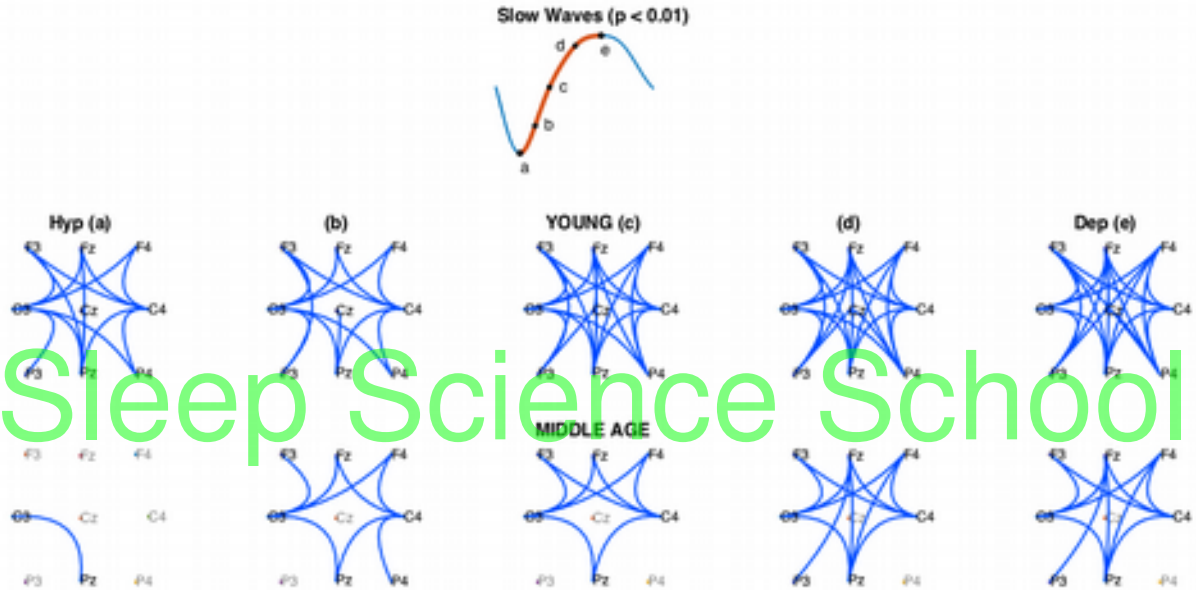
Global connectivity index: the sum of the differences in connectivity between two conditions, across all the significant pairs of electrodes

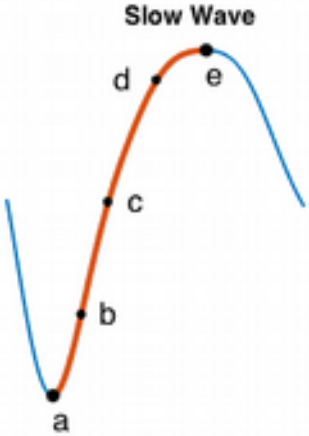
Bouchard et al. 2019 (SLEEP)

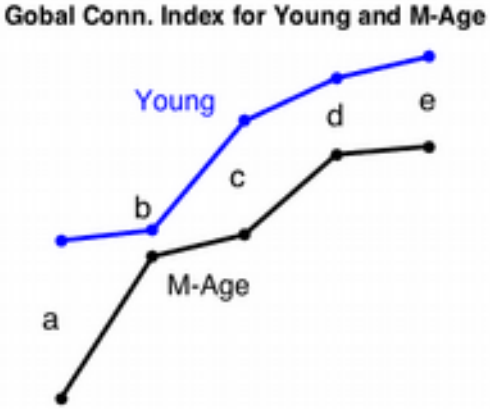
Conclusion (2)

- Older individuals showed lower EEG connectivity in N2 than the young (linked to spindles density).
- Older individuals showed higher EEG connectivity than younger ones in both REM and N3 sleep
- Older individuals do not show reduced EEG connectivity in N3 as compared to N2 during the first NREM sleep cycle
- EEG connectivity during REM sleep is lower than in N3 (data not shown)
- EEG connectivity in N2 and REM sleep linked to cognition (data not shown)

PLI during the transition between SW hyperpolarization and depolarization (contant delay)







Global connectivity index: the sum of the differences in connectivity between two conditions, across all the significant pairs of electrodes

To connect or not connect during sleep: this is the question!

Brain imaging (EEG, MEG, MRI, fMIR): new insights on brain areas involved in the functions of human sleep.

Next step: to understand how brain areas **interacts** to give rise to human sleep functions.

Functional connectivity is estimated by **several metrics** at **different time scale** (e.g. during all night vs SW) : unique information and processes to understand the complexity of the sleeping brain.

Age-related changes in **fMRI functional connectivity, NREM EEG coherence, synchronization during slow-waves**.

Age-related change in functional connectivity during sleep may very well underlying cerebral and cognitive health in aging.

NREM/REM sleep:
Age-related changes in sleep dependent consolidation

Neuron — Article

Old Brains Come Uncoupled in Sleep: Slow Wave-Spindle Synchrony, Brain Atrophy, and Forgetting

Highlights
- Precise coupling of NREM slow waves and spindles facilitates memory consolidation
- Aging impairs slow wave-spindle coupling, leading to

Authors
Randolph F. Helfrich, Bryce A. Mander, William J. Jagust, Robert T. Knight, Matthew P. Walker

Neurobiology of Aging

Sleep spindles: a physiological marker of age-related changes in gray matter in brain regions supporting motor skill memory consolidation

Cerebral Cortex December 2014;24:3305–3320
doi:10.1093/cercor/bht188
Advance Access publication July 30, 2013

Impaired Prefrontal Sleep Spindle Regulation of Hippocampal-Dependent Learning in Older Adults

Bryce A. Mander[1], Vikram Rao[1], Brandon Lu[1], Jared M. Saletin[1], Sonia Ancoli-Israel[2], William J. Jagust[3,4] and Matthew P. Walker[1,4,5]

HHS Public Access
Author manuscript

Age-related Changes in the Sleep-dependent Reorganization of Declarative Memories

Rebecca M. C. Spencer

White Matter Structure in Older Adults Moderates the Benefit of Sleep Spindles on Motor Memory Consolidation

fMRI and Sleep Correlates of the Age-Related Impairment in Motor Memory Consolidation

Stuart M. Fogel, Geneviève Albouy, Catherine Vien, Romana Popovici, Bradley R. King, Rick Hoge, Saad Jbabdi, Habib Benali, Avi Karni, Pierre Maquet, Julie Carrier, and Julien Doyon

Brief Communication

Insufficient chunk concatenation may underlie changes in sleep-dependent consolidation of motor sequence learning in older adults

Frontiers in Aging Neuroscience

Motor Performance Is not Enhanced by Daytime Naps in Older Adults

Cerebral Activation During Initial Motor Learning Forecasts Subsequent Sleep-Facilitated Memory Consolidation in Older Adults

RESEARCH ARTICLE

Sleep benefits consolidation of visuo-motor adaptation learning in older adults

Emma Manoni, Reggi Baran, Rebecca M. C. Spencer

Enhancing slow-waves and spindles to enhance memory consolidation during sleep in the older population

Transcranial Alternating Current Stimulation

Acoustic Stimulation during sleep

Enhancing slow-waves and spindles
Transcranial stimulation

Behavioral/Cognitive

Promoting Sleep Oscillations and Their Functional Coupling by Transcranial Stimulation Enhances Memory Consolidation in Mild Cognitive Impairment

Julia Ladenbauer, Josef Ladenbauer, Nadine Külzow, Rebecca de Boor, Elena Avramova, Ulrike Grittner, and Agnes Flöel

Neurobiology of Aging

Memory improvement via slow-oscillatory stimulation during sleep in older adults

Carmen E. Westerberg, Susan M. Florczak, Sandra Weintraub, M. Marsel Mesulam, Lisa Marshall, Phyllis C. Zee, Kim A. Paller

NeuroImage

journal homepage: www.elsevier.com/locate/ynimg

Brain stimulation during an afternoon nap boosts slow oscillatory activity and memory consolidation in older adults

Julia Ladenbauer, Nadine Külzow, Sven Passmann, Daria Antonenko, Ulrike Grittner, Sascha Tamm, Agnes Flöel

Enhancing slow-waves and spindles
Acoustic stimulations

ANNALS of Clinical and Translational Neurology
Open Access

RESEARCH ARTICLE

Acoustic enhancement of sleep slow oscillations in mild cognitive impairment

Nelly A. Papalambros[1,2], Sandra Weintraub[3,4], Tammy Chen[1,2], Daniela Grimaldi[1,2], Giovanni Santostasi[1,5], Ken A. Paller[6], Phyllis C. Zee[1,2] & Ronell G. Malkani[1,2]

[1]Department of Neurology, Northwestern University Feinberg School of Medicine, Chicago, Illinois
[2]Center for Circadian and Sleep Medicine, Northwestern University Feinberg School of Medicine, Chicago, Illinois
[3]Mesulam Center for Cognitive Neurology and Alzheimer's Disease, Northwestern University Feinberg School of Medicine, Chicago, Illinois
[4]Department of Psychiatry and Behavioral Sciences, Northwestern University Feinberg School of Medicine, Chicago, Illinois
[5]DeepWave Technologies, Encinitas, California
[6]Department of Psychology, Northwestern University, Evanston, Illinois

frontiers in Human Neuroscience
ORIGINAL RESEARCH

Acoustic Enhancement of Sleep Slow Oscillations and Concomitant Memory Improvement in Older Adults

Nelly A. Papalambros[1], Giovanni Santostasi[2], Ronell G. Malkani[3], Rosemary Braun[4], Sandra Weintraub[5], Ken A. Paller[6] and Phyllis C. Zee[1,7]*

[1]Center for Circadian and Sleep Medicine, Department of Neurology, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA, [2]Mathematics Division, Feinberg School of Medicine, Northwestern University, Chicago, IL, USA, [3]Department of Engineering Sciences and Applied Mathematics, Northwestern University, Evanston, IL, USA, [4]Cognitive Neurology and Alzheimer's Disease Center and Department of Psychiatry and Behavioral Sciences, Northwestern University, Chicago, IL, USA, [5]Department of Psychology, Northwestern University, Evanston, IL, USA

ORIGINAL ARTICLE

Using Oscillating Sounds to Manipulate Sleep Spindles

James W. Antony PhD[1,2], Ken A. Paller PhD[1,3]

[1]Interdepartmental Neuroscience Program, Northwestern University, Evanston, IL 60208; [2]Princeton Neuroscience Institute, Princeton University, Princeton, NJ 08544; [3]Department of Psychology, Northwestern University, Evanston, IL 60208

Introduction: EEG oscillations known as sleep spindles have been linked with various aspects of cognition, but the specific functions they signal remain controversial. Two types of EEG sleep spindles have been distinguished: slow spindles at 11–13.5 Hz and fast spindles at 13.5–16 Hz. Slow spindles exhibit a frontal scalp topography, whereas fast spindles exhibit a posterior scalp topography and have been preferentially linked with memory consolidation during sleep. To advance understanding beyond that provided from correlative studies of spindles, we aimed to develop a new method to systematically manipulate spindles.
Aims and Methods: We presented repeating bursts of oscillating white noise to people during a 90-min afternoon nap. During stage 2 and slow-wave sleep, oscillations were embedded within contiguous 10-s stimulation intervals, each comprising 2 s of white noise amplitude modulated at 12 Hz (targeting slow spindles), 15 Hz (targeting fast spindles), or 50 Hz followed by 8 s of constant white noise.
Results: During oscillating stimulation compared to constant stimulation, parietal EEG recordings showed more slow spindles in the 12-Hz condition, more fast spindles in the 15-Hz condition, and no change in the 50-Hz control condition. These effects were topographically selective, and were absent in frontopolar EEG recordings, where slow spindle density was highest. Spindles during stimulation were similar to spontaneous spindles in standard physiological features, including duration and scalp distribution.
Conclusions: These results define a new method to selectively and noninvasively manipulate spindles through acoustic resonance, while also providing new evidence for functional distinctions between the 2 types of EEG spindles.
Keywords: sleep spindles, oscillations, memory consolidation.

Precious collaborators

Undergraduate, graduate, post-graduate students, research, research associate

Marjolaine Lafortune
Véronique Latreille
Nicolas Martin
Jonathan Dubé
Maude Bouchard
Pierre-Olivier Gaudreault
Véronique Daneault
Justin Bouvier
Thomas Lehoux
Tarek Lajnek
Samuel Deslaurier-Gauthier

Center for advanced research in sleep medicine (CÉAMS)

Jean-Marc-Lina, École de Technologie Supérieure
Jean-François Gagnon, UQAM
Nadia Gosselin, UdeM
JY Montplaisir, UdeM
Sonia Frenette
Jean Paquet
Gaétan Poirier
Christophe Bedetti

Other labs

Julien Doyon, BIC, MNI, McGill
Pierre Maquet, Université de Liège
Célyne Bastien, Université Laval
Alan Evans, McGill University
Pierre Bellec, CRIUGM, UdeM
Pierre Jolicoeur, CERNEC, UdeM
Karim Jerbi, CERNEC, UdeM

CIHR IRSC
NSERC CRSNG
Fonds de recherche Nature et technologies Québec
QBIN
Fonds de recherche Santé Québec