NEAR-INFRARED LIGHT APPLIED TO THE BRAIN: A STUDY OF PHOTONS' PROPAGATION USING MONTE CARLO SIMULATIONS

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1. Introduction

Alzheimer's disease : still incurable neurodegenerative disease

→ **Transcranial photobiomodulation (tPBM)**

Consists of red and Near Infrared (NIR) light applied transcranially to the brain (λ=600-1000nm) for therapeutic objectives

How much energy is deposited in each brain region?

Monte Carlo = **probabilistic method** to model light propagation in 3D turbid media *(Prahl et al. 1989)*

⇒ Use Monte Carlo simulation to **simulate NIR light propagation** in the brain

⇒ Previous work modelling a single source showed that NIR light can go through **3-4cm deep** (*Li et al. 2017*)

⇒ Examine light propagation using an **existing multisource** device

⇒ Examine the total quantity of light deposited **region by region**

⇒ Compare 1 **young** and 1 **aged** healthy brain

2. Methods

⇒ Tested wavelengths **670 / 810nm**

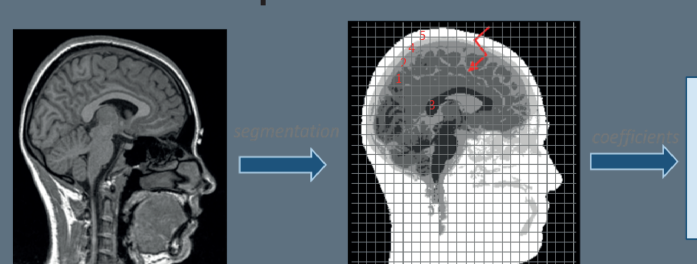
⇒ Segmentation of T1w MRI images: GM, WM, CSF, skull, scalp

⇒ Each tissue has its combination of optical coefficients

μ_a = absorption coeff.
μ_s = scattering coeff.
***n** = refractive index*
***g** = anisotropy factor*

⇒ **Simulation using mcxyz** (*Jacques et al. 2019*):

- Launch a photon packet (determine coordinates / direction)
- Determine step size and move photons according to angle = actualize coordinates
- Remove absorbed weight ⇒ verify if weight is below cutoff
- If no: det. step size and move photons to the next interaction site



μ_a: absorption coefficient
μ_s: scattering coefficient
g: anisotropy
n: refractive index

670nm	WM	GM	CSF	skull	scalp
µa	0.07	0.02	0.004	0.0208	0.034
µs	40.1	8.4	0.3	x	x
µ's		x	0.01	1.19	2.53
g	0.85	0.9	1	0.89	0.89
n	1.37	x	x	1.37	1.37
810nm	**WM**	**GM**	**CSF**	**skull**	**scalp**
µa	0.092	0.028	0.0026	0.011	0.019
µs	38	7.3	0.1	x	x
µ's		x	0.01	1.92	1.84
g	0.87	0.9	0.9	0.89	0.89
n	1.37	x	x	1.37	1.37

Simulations
n=10^9 photons

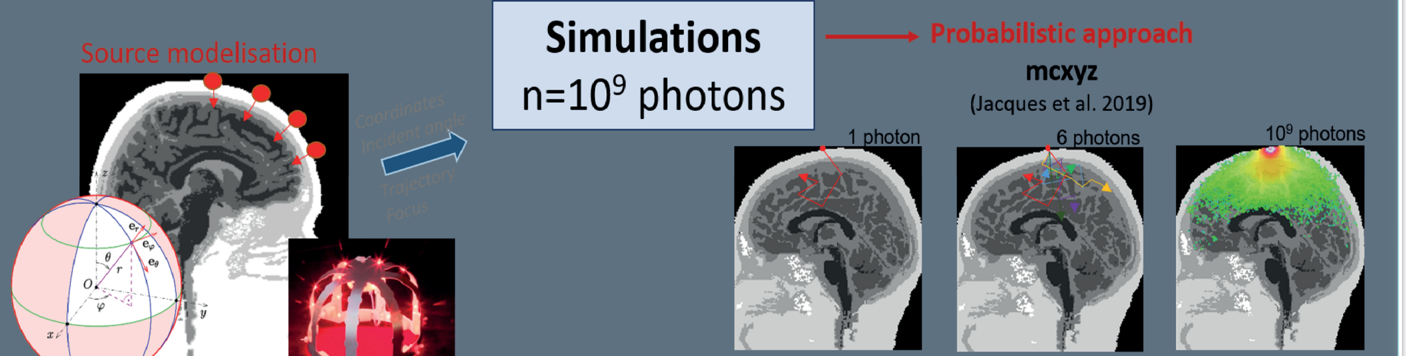
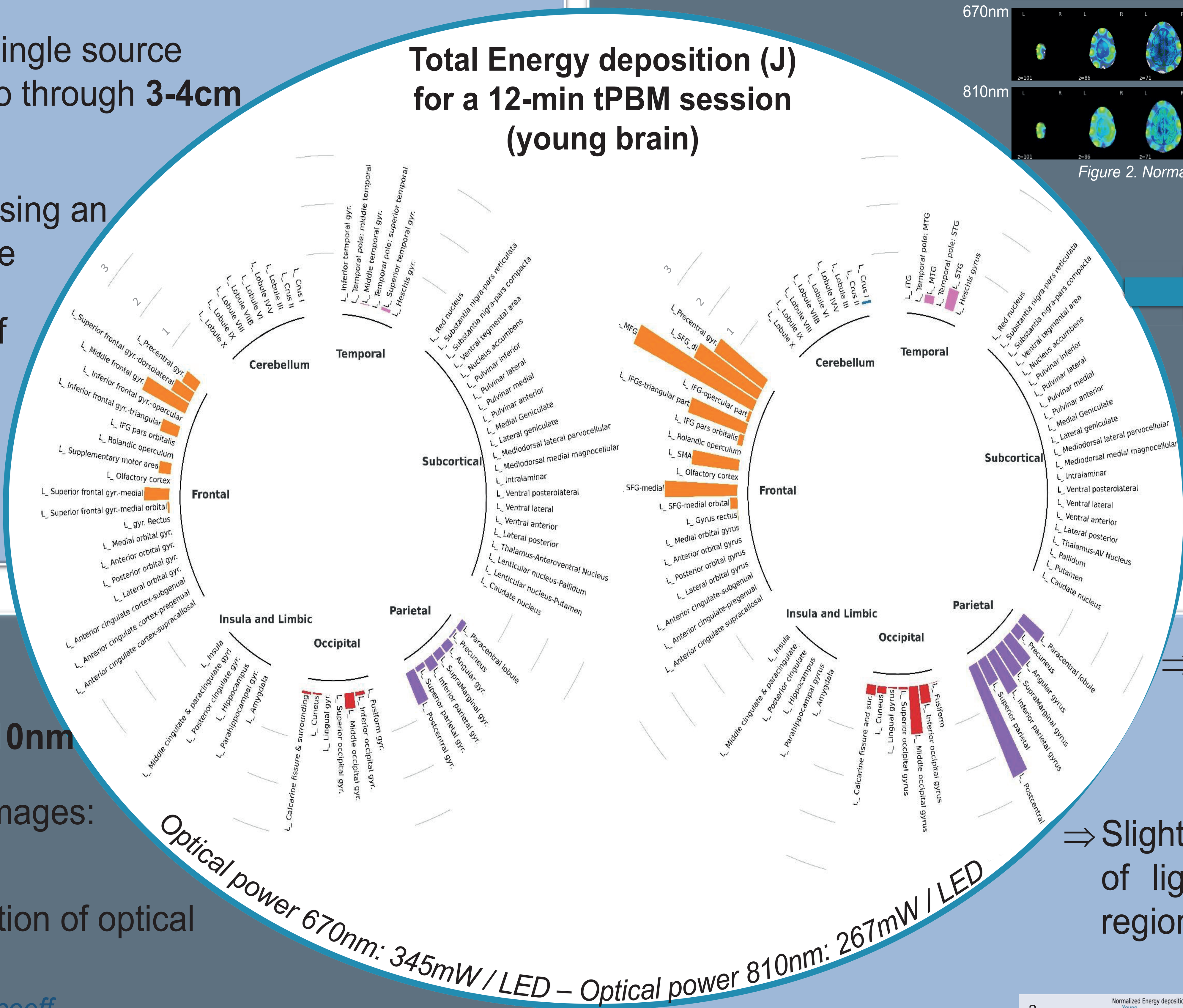


Figure 1. Schematic representation of the methods



3. Results

⇒ Light deposition attenuated **exponentially** following Beer's Lambert Law

⇒ Red and NIR lights were mainly deposited in **superficial regions**

⇒ Photons were found until **~ 4cm** below the scalp surface

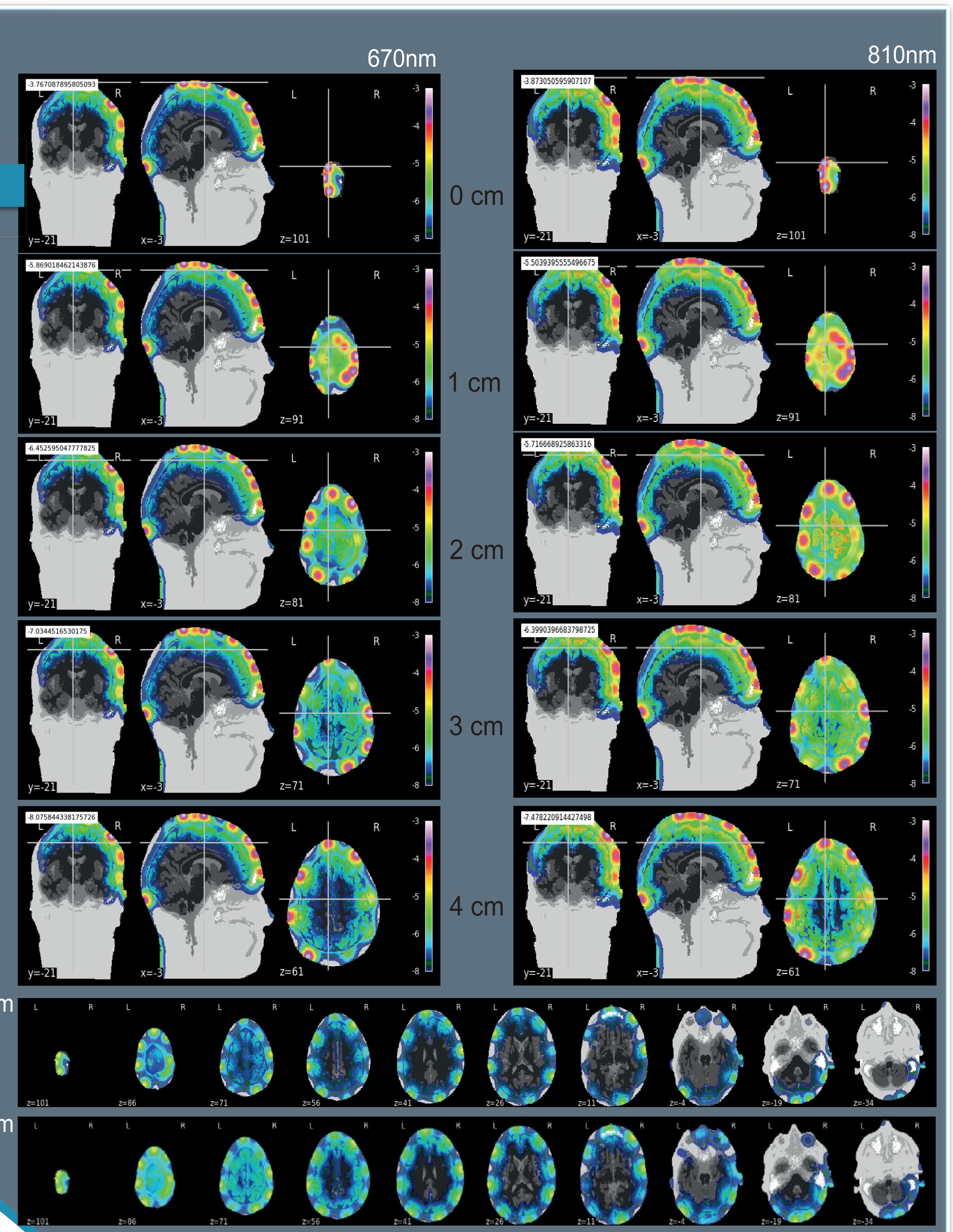


Figure 2. Normalised energy deposition in log (W/mm3 per Watt applied at each source) for 670nm light (left) and 810 nm light (right)

⇒ **810nm** light propagated **deeper than 670nm** light

⇒ Light deposition mainly in the **frontal, parietal and occipital** regions

⇒ Light propagated globally similarly in young and aged brains

⇒ Slight differences in the repartition of light deposition in the frontal regions

⇒ **90,21%** of 670nm light and **82,81%** of 810nm light absorbed in the scalp

⇒ **6,42% of** 670nm light and 8,42% of 810 nm light absorbed in the skull

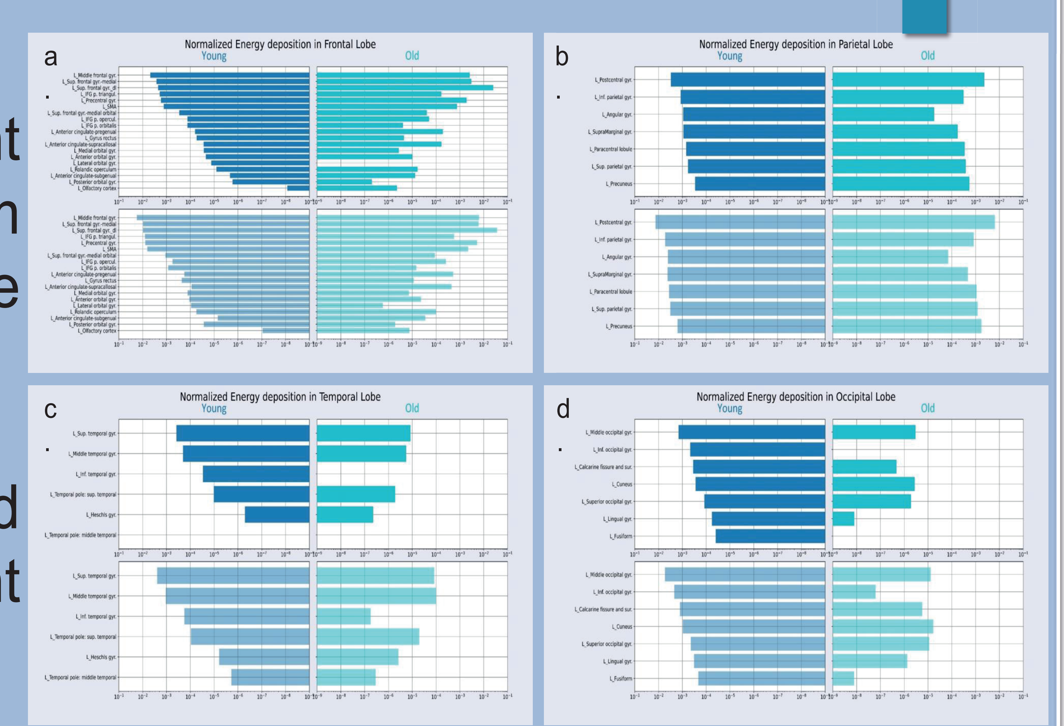


Figure 3. Normalized energy deposition in log (W/mm3 per Watt applied at each source) region by region, in the young (dark blue) and old (light blue) brains.

4.Conclusions

⇒ Red and NIR light is able to penetrate inside the brain

⇒ **Superficial** regions of the cortex can be targeted by tPBM, **not deep** regions

⇒ Light deposition is **not homogeneous** across brain lobes:

- Effect of the localisation of LEDs sources onto the head?
- Effect of scalp /skull thickness?

⇒ Limitation of this study: vasculature and hairs were not modelled

References
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