fNIRS原理簡介

近紅外腦功能資料處理工作坊

http://www.ym.edu.tw/~cflu/CFLu_course_fnirsWorkshop.html

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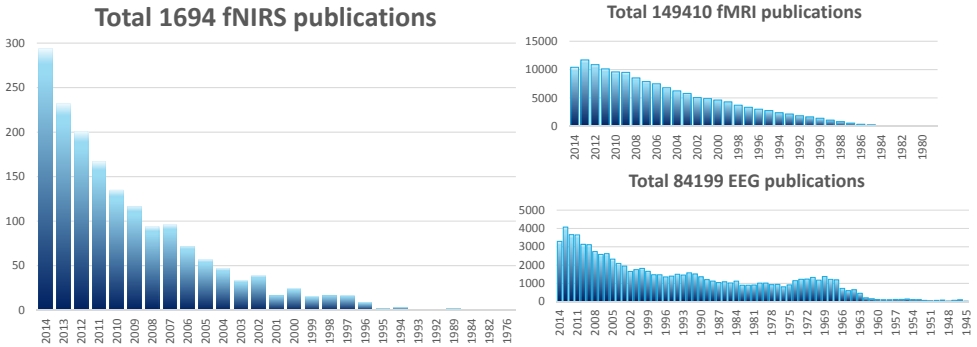
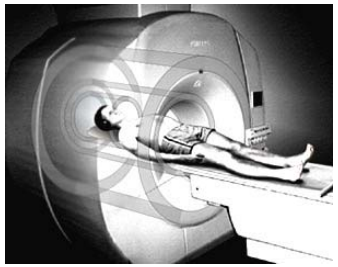
講習內容安排

- 09:10~11:00 fNIRS原理簡介
- 10:10~11:00 fNIRS實驗設計
- 11:10~12:00 fNIRS探頭擺放設計與位置確認
- **12:00~13:30 用餐與休息**
- 13:30~14:20 fNIRS實驗操作技巧
- 14:30~15:20 fNIRS標準訊號處理流程
- 15:30~16:20 fNIRS數據結果呈現與相關性分析

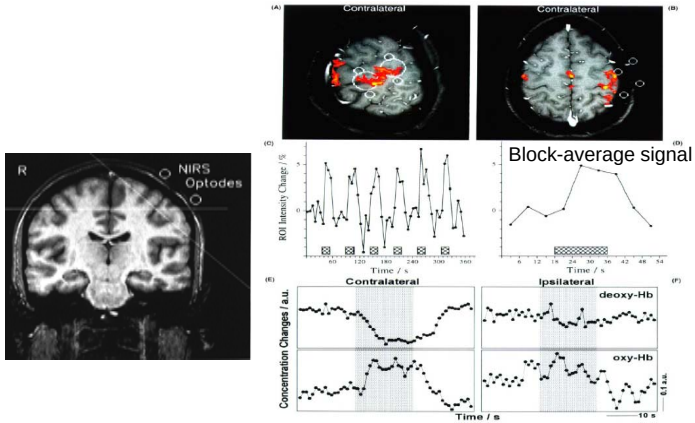
PubMed – fNIRS publications



EEG/MEG	fMRI	fNIRS
		
• **High temporal resolution** • **Neural activity** • Superficial cortex • **Open environment** • **Low cost** • **Wearable system** • Physiological/Electronic noise	• Low temporal resolution • BOLD signal • **Superficial & deep cortex** • Close environment • High cost • **High spatial resolution** • **High tissue contrast** • Magnetic and posture limitation	• **High temporal resolution** • Hemoglobin oxygenation • Superficial cortex • **Open environment** • **Low cost** • **Wearable system**

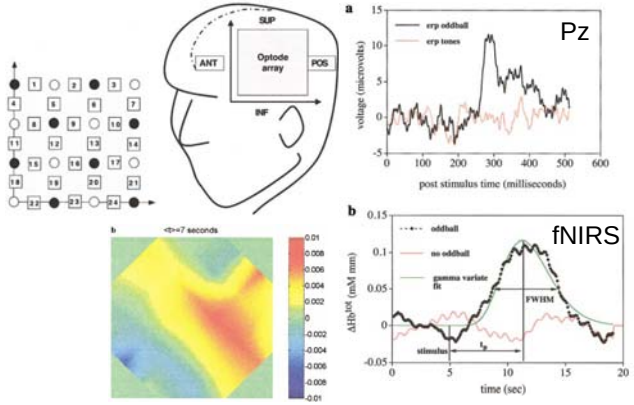
fMRI vs. fNIRS

J CBF & Metabolism. 1996, 16:817-826.



- **Decreases in deoxy-Hb, which reduce the microscopic susceptibility effects, yield fMRI signal increases.**

fNIRS vs. EEG



Kennan et al. NeuroImage 2002: 16, 587-592.

fNIRS Instruments

< portable/movable >

ISS instrument

NIRx NIRScount

Hitachi ETG-4000

DYNOT system

< wearable >

NIRx NIRSport 8x8

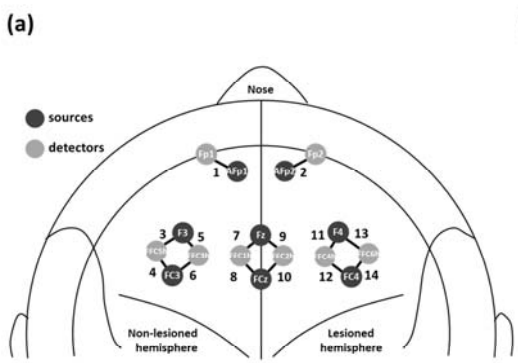
Hitachi WOT-100

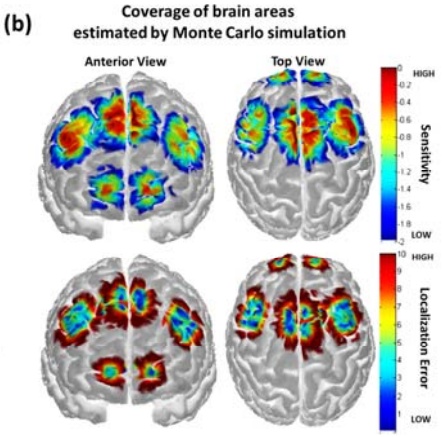
Size, Does it matter?

Critical Issues of fNIRS

1. Validation of optodes/channels locations
   (coverage of brain area)
2. Correction of motion artifacts
3. Confirmation of signal source
   (cortex or scalp)

S-D Arrangement & Experiment Design

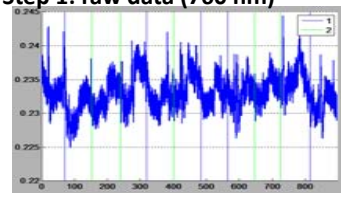




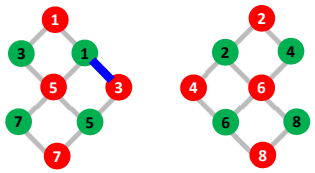
International 10-5 system

Signal Processing & Analysis

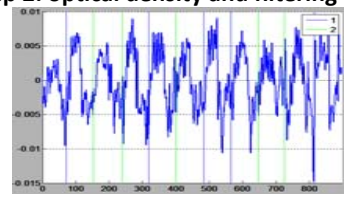
Step 1: raw data (760 nm)



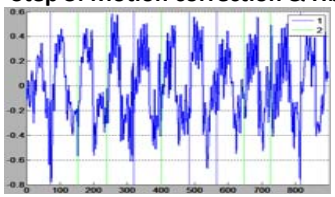
S-D arrangement



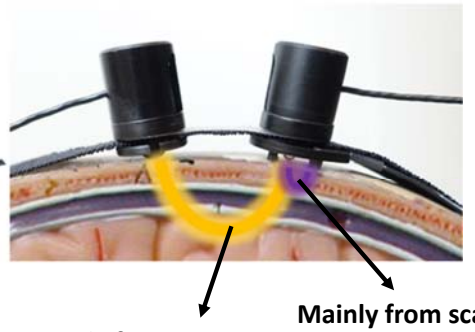
Step 2: optical density and filtering



Step 3: Motion correction & HbO/HbR conc.



Short Separation Setup



Mainly from scalp

Mainly from cortex
With partly coverage of scalp

fNIRS原理簡介

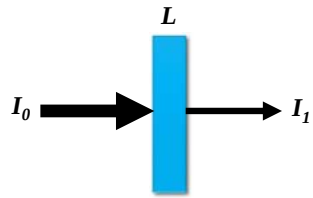
Basic Principles of fNIRS

Beer-Lambert Law

Describe the attenuation of light propagating in a homogeneous medium.

$$I_1 = I_0 \exp(-\mu_a(\lambda)L)$$

I_0: the incident light
I_1: the light leaving the medium
L : the propagation path length
μ_a : the absorption coefficient



non-scattering & homogeneous medium

A Mixture of Chromophore

The sum of the products of the concentration of each chromophore c_n with its molar extinction/absorption coefficient ε_n.

$$\mu_a(\lambda) = \sum_n \varepsilon_n(\lambda) c_n$$

< Blood >
- White blood cells and platelets <1%
- Red blood cells ~44%
- Plasma ~55%

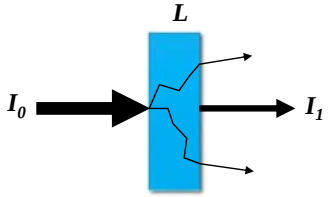
The individual extinction coefficient of each chromophore represent their absorption at a particular concentration ($cm^2 \cdot mol^{-1}$).

Scattering Events

Refractive index mismatches at boundaries.

$$I_1 = I_0 \exp(-\mu_s(\lambda)L)$$

μ_s : the scattering coefficient



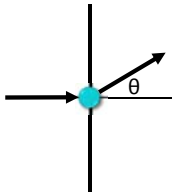
The scattering path length, defined as $1/\mu_s$, is the expected value of distance that a photon travels between scattering events.

Anisotropy Factor

The phase function, f(cosθ), describes the angular probability of photon being scattered.

The anisotropy factor, *g*, can be represented as the mean cosine of the scattering angle.

$$g = \int_{-1}^{1} cos\theta \cdot f(cos\theta) d cos\theta$$



g = 0 → isotropic scattering
g = 1 → straight line
g = -1 → complete backward scattering

Biological tissues are strongly forward-scattering media.
0.69<*g*<0.99 (48.70° >θ >8.11°)

Optical Density (OD)

OD is the amount of attenuation that occurs when light passes through an optical component.
- comes from both the absorption and scattering of light.

Transmission, $T = I_1/I_0$

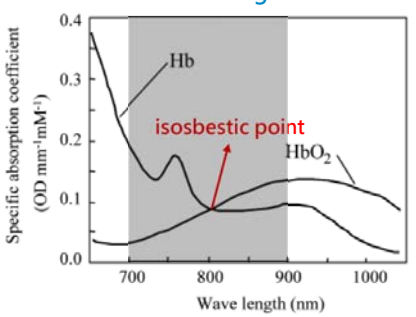
$$OD = log_{10}(1/T) = -log_{10}(T)$$

< Example >
Attenuate light by a factor of 10^3,
$T = 10^{-3}$,
$OD = -\log_{10}(10^{-3}) = 3$

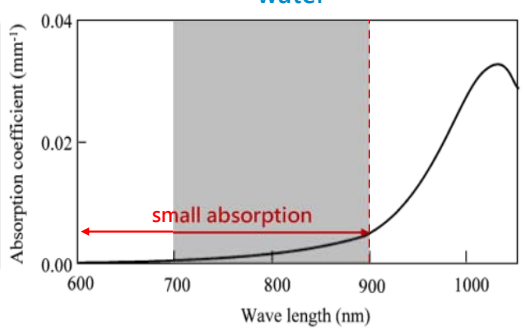
Absorption coefficients of tissues

Wavelength between 700 and 900 nm are suitable for spectroscopy

oxygenated/deoxygenated hemoglobin



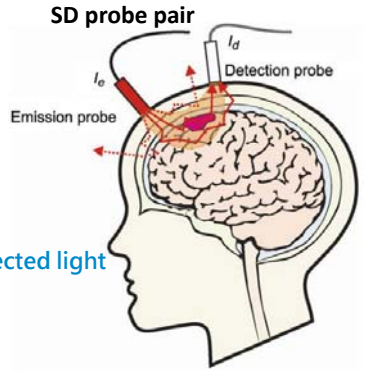
water



Photon Migration in Brain

Modified Beer-Lambert Law

$$OD = \ln\left(\frac{I_e}{I_d}\right) \approx \mu_{a\,head}\langle L_{head}\rangle + G$$



$\mu_{a\,head}$: assume the absorption in the head is homogeneous
$\langle L_{head}\rangle$: the mean optical path length of the detected light
G: the scattering loss (cannot be measured)

Modified Beer-Lambert Law

Based on an assumption that the scattering loss does not change during the measurement period.

$$\Delta OD = ln\left(\frac{I_e}{I'_d}\right) - ln\left(\frac{I_e}{I_d}\right) = ln\left(\frac{I_d}{I'_d}\right) = \Delta\mu_{a\,head}\langle L_{head}\rangle$$

Change caused by brain activations (dynamics of HbO and HbR)

Brain Activation

Assumption:

- the concentration of hemoglobin is only changed during the measurement period by brain activation.

$$\Delta\mu_{a\,head}(\lambda) = \varepsilon_{HbO}(\lambda)\Delta c_{HbO} + \varepsilon_{HbR}(\lambda)\Delta c_{HbR}$$

Measurements under two or more wavelengths (760 and 850 nm) are demanded.

Partial Optical Pathlength

Assuming that the head consists of several homogeneous tissues.

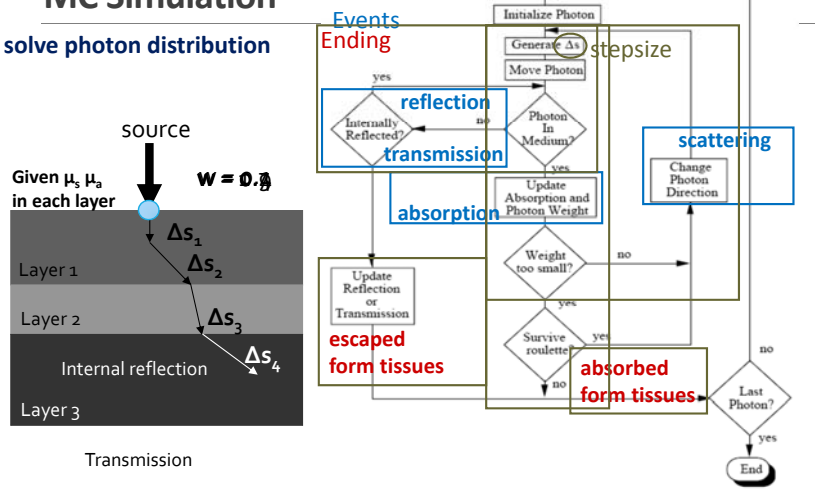
Partial optical pathlength

- The mean optical pathlength that the detected light travels in each tissue region

$$\Delta OD = \sum_{i=1}^{M} \Delta\mu_{a\,i}\langle L_i\rangle$$

MC Simulation

solve photon distribution



Models for MC Simulation

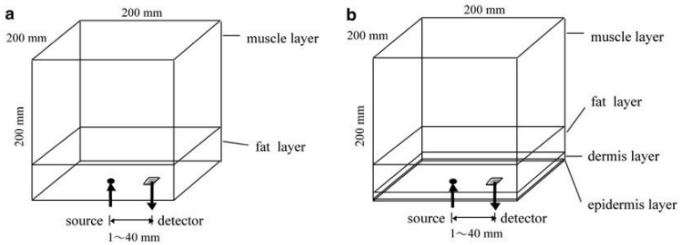
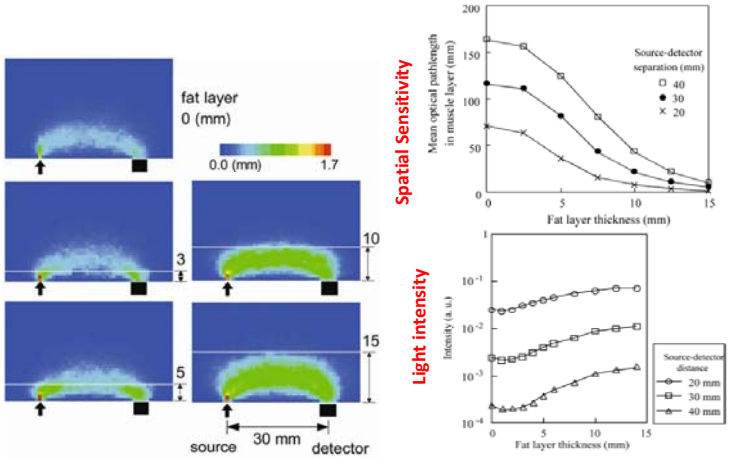


Table 2.1 Reduced scattering coefficient and absorption coefficient of each layer

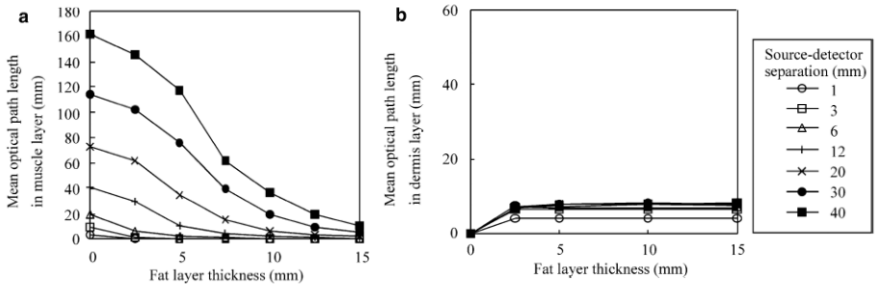
Layer	Reduced scattering coefficient (mm^{-1})	Absorption coefficient (mm^{-1})	References
Epidermis	5.0	5.9	[21]
Dermis	1.3	0.03	[22]
Fat	1.2	0.003	[23]
Muscle	0.6	0.02	[24]

Effect of Fat Layer



Effect of the Skin

The effect of blood in the skin can be ignored when the source-detector separation is large (>20 mm).

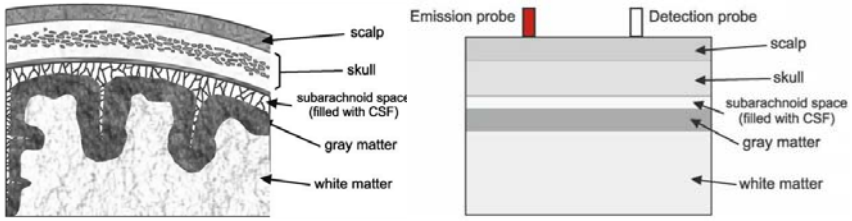


Head Model

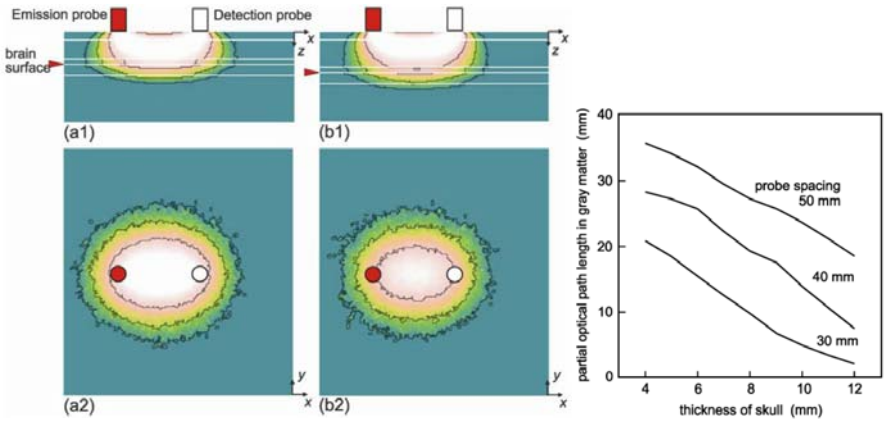
Table 3.1 Typical optical properties of tissues of an adult head model at 800-nm wavelength

Tissue types (mm^{-1})	Transport scattering coefficient (mm^{-1})	Absorption coefficient (mm^{-1})
Scalp	1.9	0.018
Skull	1.6	0.016
Subarachnoid space (CSF)	0.24	0.004
Gray matter	2.2	0.036
White matter	9.1	0.014

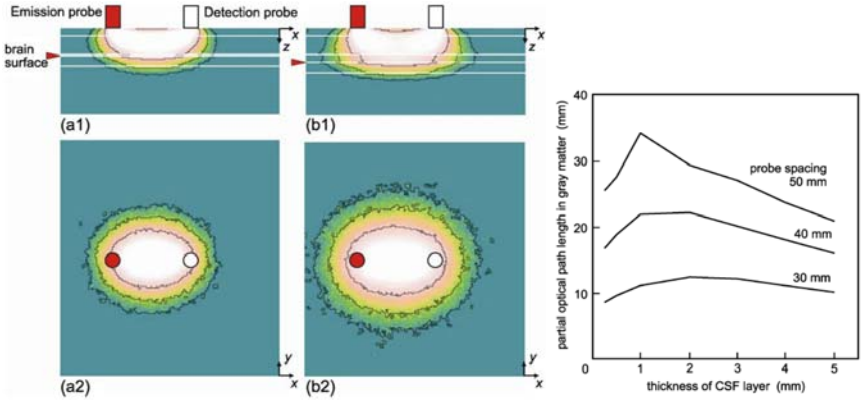
Data chosen from the reported data for dermis [64], pig skull [62], CSF layer [16], and human brain [63]



Influence of Skull Layer



Influence of CSF Layer



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Q & A

Thanks for your attention :)