fNIRS GLOSSARY PROJECT

LIST OF TERMS (MARCH 2025)

Avalanche Photodiode

Definition: Avalanche photodiodes utilize the avalanche multiplication process to achieve higher electric output. The avalanche photodiode resembles a PIN photodiode except for the insertion of an additional p-type multiplying region. Most of the incident photons are absorbed in the intrinsic ('I') region and electron-hole pairs are first generated in this region as in the PIN photodiode. The holes drift toward the p-type region ('P') and the electrons toward the n-type ('N'). The electrons, before reaching the n-type region, pass through a p-type multiplying region. If the electrons have undergone sufficient acceleration on reaching the multiplying region, new electron-hole pairs are generated by the collision- ionization process. The newly generated electron-hole pairs themselves generate more electron-hole pairs. The drawbacks to avalanche photodiodes are the high bias voltage needed, and the temperature compensation necessary for stable operation.

Alternative definition: An avalanche photodiode (APD) is a type of semiconductor photodetector used to detect low levels of light in applications such as fNIRS. It is based on the principle of avalanche multiplication, which occurs when an electron in the photodiode collides with an atom and generates a cascade of secondary electrons, resulting in a much larger current than would be caused by a single photon.

Synonym:

References: E. Hui Pan. Fiber Optics Weekly Update. Information Gatekeepers Inc.

Related terms: Photomultiplier tube, Detector, Sensor, Silicon Photomultiplier

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Optode

Definition: An optode is the distal end of an fNIRS system which interfaces with the surface of the tissue being measured. Optodes can contain a single source (source optode), a single detector (detector optode), or a source accompanied by a short-separation detector.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2005.08.008

https://biomedical.njit.edu/sites/biomedical/files/fNIRS%20Optode%20Helmet%20Construct.pdf

Related terms: source; detector; emitter; emission, receiver, transmitter

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Optode array

Definition: Relative arrangement of linked sources and detectors on a region of interest.

Alternative definition: A schematic arrangement of sources and detectors to create a pattern of measurement channels.

Synonym: Probe array; fNIRS array; Channel configuration; fNIRS-sensor configuration; Source–detector array, fNIRS Montage

References: https://doi.org/10.1117/1.NPh.5.3.035010

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Probe design; Optode placement, topographic layout, Montage

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Power supply

Definition: Power supply is an electronic device that provides a stable voltage, current, and frequency required for other devices to function correctly. This device maintains a stable rated wattage output consistently.

Alternative definition:

Synonym:

References: https://doi.org/10.1109/TPEL.2019.2941528

Related terms:

Probe

Definition: A probe or probeset is the arrangement of optodes on the head. Probes can be placed according to the international 10-20 system and/or other anatomical landmarks. The optodes (emitters and detectors) are typically located in a grid with fixed inter-optode-distances for long-distance and short-distance channels.

Alternative definition:

Synonym: probeset

References: -

Related terms: topographic layout, optode placement, fNIRS caps, inter-optode-distance

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Sampling frequency

Definition: The number of samples per second collected from a continuous signal through analog-to-digital conversion.

Alternative definition: Number of data samples collected per unit of time (in Hz) from each channel.

Synonym: Sampling Rate

References: https://doi.org/10.3389/fpsyg.2017.00093

Related terms:

Saturation

Definition: In terms of a photodiode, if the incident optical power continues to increase but the photocurrent output stops growing, it indicates that the photodiode has reached saturation. The saturation limit can be adjusted by reducing the resistance seen by the load or changing the reverse bias voltage applied. The saturation point represents the upper boundary of the photodiode's linear range, while the lower boundary of that linear range is determined by the noise. Beyond this range, the photodiode operates in a nonlinear manner.

Alternative definition:

Synonym: photocurrent output limit

References: https://doi.org/10.1364/OE.422478

https://www.thorlabs.com/images/TabImages/Photodetector_Lab.pdf

Related terms: Photodiode

Source-detector separation

Definition: Source-detector separation (SDS) refers to the physical distance between each fNIRS source-detector pair of optodes. It determines the signal-to-noise ratio (SNR), the number of measurable photons, depth sensitivity to the change in hemoglobin, the allowed amount of sources/detectors/channels, and the size of covered regions. Depending on the population being studied (e.g., adults vs. infants) and the purpose of the channels (e.g., measuring oxygenated hemoglobin in the brain vs. removing the confounding effects of superficial tissue physiology), the optimal SDS will vary. In a reflection geometry, larger SDS increases depth sensitivity (i.e., to deep regions further from the surface), at the cost of reduced total detected intensity.

Alternative definition: The inter-optode distance is the spatial distance between a source and a detector. In circular geometries it is defined as the length of the chord between the optodes.

Synonym: Source-detector separation range, Source-detector separation, inter-optode distance

References: https://doi.org/10.1117/1.NPh.2.2.025005

https://doi.org/10.1111/cpf.12156

https://doi.org/10.1117/1.JBO.21.9.091307

Related terms: short-channel separation, source-detector pair

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Artifact

Definition: In the context of fNIRS, an artifact is a disturbance of the fNIRS signal that makes the identification of physiologically relevant information in the fNIRS signal difficult or impossible. Generally it is a component of the fNIRS signal that is not induced by neuronal activity and may thus contaminate the measured hemodynamic response. Common sources of artifact in fNIRS data include relative movement between the optodes and the scalp (i.e. motion artifacts), optical signal changes caused by non-brain function related physiological variations (e.g., effects of blood flow changes in the scalp or respiration), environmental variations (e.g., due to stray or ambient light), as well as undesired instrument fluctuations (i.e., related to the measurement equipment).

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fnins.2012.00147

https://doi.org/10.1016/j.neuroimage.2013.04.082

Related terms: Physiological Noise, Filtering, Noise, Motion Correction, Accelerometer, Gyroscope, Inertial measurement Unit (IMU), Low-Pass Filter, High-Pass Filter, Band Pass Filter, baseline shift, baseline drift

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Band-pass filtering

Definition: A band-pass filter is a combination of a low-pass and a high-pass filter and has the effect of attenuating frequencies above and below the passband frequencies. In the context of fNIRS, band-pass filtering is used as a signal processing step to reduce undesired fNIRS signal frequency components that are irrelevant to the brain functions of interest, i.e. task or stimulus evoked hemodynamic responses or resting-state hemodynamics.

Alternative definition:

Synonym: filtering

References:

https://doi.org/10.3389/fnhum.2019.00331

https://doi.org/10.1542/peds.2015-2326

http://dx.doi.org/10.1136/adc.76.2.151

https://doi.org/10.3389/fnhum.2013.00864

Related terms: high-pass filtering, low-pass filtering, wavelet, temporal filtering

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Baseline Drift

Definition: A baseline drift refers to a gradual change or deviation in a signal's behavior or output over time. Changes in the contact between the sensors and the scalp, temperature variations, instrument instability, and other variables can all contribute to this change.

Alternative definition:

Synonym: Signal drift

References: https://doi.org/10.3389/fnhum.2015.00617

Related terms: Motion artifact, baseline shift

Baseline Shift

Definition: A baseline shift is an artifact in the signal that specifically refers to a rapid change in the amplitude of the signal, typically taking a few seconds or less, which results in a discontinuity in the signal. For example, when an optode moves relative to the scalp and fails to return to its original position, this will create a baseline shift in the signal.

Alternative definition:

Synonym: shift artifacts, step-like artifacts

References: https://doi.org/10.1109/EMBC46164.2021.9631014

https://doi.org/10.3389/fnins.2012.00147

https://doi.org/10.3390/brainsci11050606

Related terms: artifact, spikes, motion artifacts, noise, baseline drift

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BIDS

Definition: The Brain Imaging Data Structure (BIDS) is a standardized format for organizing and describing neuroimaging data such as fMRI, EEG, fNIRS as well as behavioral data, among others, making it accessible to and shareable with a wide range of researchers from diverse backgrounds. It is based on a formalized file and folder structure and JSON (Javascript Object Notation)-based metadata files with controlled vocabulary. The top-level directory contains subdirectories for each subject, and each subject directory contains subdirectories for each session and modality. It includes the core specification as well as extensions for specific brain imaging modalities and other types of data. (https://bids.neuroimaging.io/)

Alternative definition:

Synonym:

References: https://doi.org/10.1038/sdata.2016.44

https://doi.org/10.1117/1.NPh.10.2.023515

https://doi.org/10.1162/imag_a_00103

https://doi.org/10.31219/osf.io/7nmcp

Related terms: SNIRF, Open Science, Open Data, Data Structure, Standardization

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Block average

Definition: A block average is the response obtained from segmenting the fNIRS measurement with respect to the task or stimulus onset and offset and averaging these segments across trials of a given condition. The time window for block averaging usually starts with a baseline period and is long enough to capture the hemodynamic response to the stimulus presented. Block averaging can be done on the single-subject level or/and on the group level.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.NPh.8.2.025008

https://doi.org/10.1016/j.dcn.2010.07.004

https://doi.org/10.1111/nyas.13948

https://doi.org/10.1117/1.2166632

Related terms: block design, event-related averaging

Boxcar function

Definition: The boxcar function is a function which has values 0 everywhere except for specific time window(s) where its value is a constant. With respect to experimental studies, the boxcar function serves as a representation of time periods during which specific events occur (e.g., a stimulus or a nuisance factor). The function typically takes a rectangular form with a value of 1 when the event is 'on' with a width equal to the duration of the stimulus and 0 when the event is 'off'. In data analysis (e.g., General Linear Model), the boxcar function is used to model the experimental design or any other relevant binary (on/off) regressor or factor. In these use-cases, a value of 0 usually corresponds to the absence of the factor (e.g., no stimulation or “off” state, i.e., interstimulus interval), and a value of 1 corresponds to the presence of the factor (e.g., stimulus presentation or “on” state, i.e., stimulus block).

Alternative definition:

Synonym:

References: https://doi.org/10.1016/B978-012372560-8/50003-6

https://doi.org/10.1016/B978-012372560-8/50014-0

https://doi.org/10.1006/nimg.1998.0351

Related terms: regressor, general linear model, block design, design matrix

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Butterworth filter

Definition: Butterworth filter is a type of Infinite Impulse Response (IIR) filter characterized by a maximally flat response in the passband (the frequencies that can pass through the filter) and a gradual roll-off in the stopband, the steepness of which depends on the order of the filter. The passband is defined by the cut-off frequency.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1109/78.678493

https://doi.org/10.1016/B978-0-12-818946-7.00001-9

Related terms: filter, Cut-off frequency, Chebishev filter

Chebyshev filter

Definition: A Chebyshev filter is a type of Infinite Impulse Response (IIR) filter that provides a specific trade-off between the sharpness of the filter's frequency response and the amount of ripple allowed in either the passband or the stopband. It is designed to achieve a steeper roll-off and smaller absolute errors than a Butterworth filter but at the expense of increased ripple in the frequency response.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1002/cta.4490080205

Related terms: filter, Butterworth filter

Coefficient of variation

Definition: The coefficient of variation (CV) is the ratio of the standard deviation of a signal to its mean value. In the context of fNIRS analyses, CV is often used to detect channels with poor signal quality.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.chemolab.2013.07.007

Related terms: Data quality assessment, scalp coupling index, signal quality metrics, noisy channels, channel rejection, Signal-to-noise-ratio (SNR)

Contrast-to-noise ratio (CNR)

Definition: The contrast-to-noise ratio (CNR) is the detection sensitivity per sampling unit. In the context of fNIRS, this can refer to the ratio of the amplitude variation δI of a hemodynamic response to the level of noise $ \sigma $in the data, i.e. CNR = $frac{\delta I}{\sigma} $or in the context of general image data analysis, it can refer to the average signal/intensity recovered in a selected region-of-interest (ROI) subtracting that of the background region, and divided by the spatial variations of the recovered image data in either the background or ROI.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.8.1.012101

https://doi.org/10.1117/1.1852553

Wang, L. V., & Wu, H.-I. (2007). Biomedical Optics: Principles and Imaging. John Wiley & Sons

Patterson MS and Foster FS, “The improvement and quantitative assessment of b-mode images produced by an annular array/cone hybrid,” Ultrasonic Imaging, vol. 5, no. 3, pp. 195–213, 1983.

Davies, E. R. (2004). Machine vision: theory, algorithms, practicalities. Elsevier.

Digital Image Processing (3rd Edition)February 2006. Gonzalez and Woods. Prentice-Hall

Related terms: signal-to-noise ratio, noise

Regularization

Definition: A range of algebraic operations that introduce a small perturbation on a tensor in order to alter its determinant. Consequently, regularization changes the condition number of a matrix. The range of applications of regularization is vast e.g. perhaps for enabling or stabilizing matrix inversion, for altering the prominence of some dimensions of the tensor over others, for

increasing derivability e.g. smoothing, etc. By and large, the most popular regularization approach is Tikhonov's which attacks the main diagonal isotropically and only has 1 parameter, but certainly many other regularization approaches exist with different purposes. A popular use in fNIRS is to improve the stability and accuracy of the reconstruction algorithm by introducing additional constraints. It is often used in solving the ill-posed inverse problem in image reconstruction when the data being used for reconstruction is noisy and can help to reduce the effects of these sources of error on the final reconstructed image. Another form of regularization that has been used in fNIRS analysis is sparsity regularization, which adds a penalty term proportional to the L1 norm of the changes in hemoglobin concentration. This penalty term encourages the solution to be sparse, meaning that it has many zero or near-zero coefficients, which can help identify the brain regions that are most active.

Alternative definition:

Synonym:

References:

https://doi.org/10.1063/5.0015512

https://doi.org/10.1117%2F1.JBO.26.5.056001

Related terms: Moore-Penrose Pseudoinverse

Cross-chromophore test

Definition: Cross-chromophore test is an evaluation strategy for prediction models that builds on the ability of NIRS to measure multiple chromophores. As a type of out-of-distribution test, it tests for generalization across chromophores by reserving all records of one chromophore for training while using the other chromophore exclusively to quantify the model's predictive capacities.

Alternative definition:

Synonym:

References:

https://doi.org/10.1007/978-3-031-17899-3_15,

https://doi.org/10.1002/hbm.25966

Related terms:

Cut-off frequency

Definition: The cut-off frequency is usually defined as the frequency at which the gain of a filter is reduced by 3-dB from the passband gain. It defines the boundary between the passband and the stopband frequency regions of the filter, and hence the frequency components of the input signals that are preserved and attenuated. It is typically expressed in Hz.

Alternative definition: (if applicable)

Synonym:

References: Smith, S. W. (1997). The scientist and engineer's guide to digital signal processing.California Technical Publishing

Related terms: Bandpass filter, High-pass filter, Low-pass filter, Sampling frequency

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Dynamic causal modeling

Definition: Dynamic causal modeling (DCM) is a Bayesian model comparison framework used to estimate the effective connectivity between brain regions. DCM models are based on stochastic estimation of the parameters of an underpinning assumed generative model. One common DCM model is the bilinear model based on ordinary differential equations.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/s1053-8119(03)00202-7

https://doi.org/10.1016/j.neuroimage.2015.02.035

https://doi.org/10.1016/j.neuroimage.2018.04.022

https://doi.org/10.1016/j.schres.2020.11.012

Related terms: Granger causality

Dynamic Functional Connectivity

Definition: Dynamic Functional Connectivity (dFC) also called time-varying connectivity, refers to the changes in functional connectivity over time. In contrast to conventional steady state connectivity analyses, dFC analysis aims to capture the dynamic nature of brain activity and the flexible reorganization of functional coupling between brain regions or networks that occur in response to changes in task demands, environmental stimuli, or at rest.

Alternative definition:

Synonym:

References: https://doi.org/10.1007/s10334-010-0197-8

https://doi.org/10.1162/netn_a_00116

https://pubmed.ncbi.nlm.nih.gov/20006716/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3807588/

https://doi.org/10.1007/s00429-013-0634-3

Related terms: static connectivity

International 10-20 system

Definition: The International 10-20 system is a system that uses four anatomical landmarks on the head (nasion, inion, and left and right preauricular points) to standardize the placement of electroencephalography (EEG) electrodes on the scalp. In this system the placement of 21 individual electrodes are determined by their distances from the landmarks, defined as the percent of the total distance (from nasion to inion and from right to left preauricular points). 10% defines the distance between the first electrode and the anatomical landmark, and 20% defines the distance between the adjacent electrodes. The International 10-20 system and its more fine-grained successors (such as 10-10, 10-5) are important in clinical and research EEG. In fNIRS research it is sometimes used to define optode positions and corresponding cortical structures.

Alternative definition:

Synonym:

References: Jasper, H.H. (1958) The Ten-Twenty Electrode System of the International Federation. Electroencephalography and Clinical Neurophysiology, 10, 371-375.

https://doi.org/10.1016/j.neuroimage.2009.02.006

https://doi.org/10.1016/j.neuroimage.2003.08.026

Related terms: International 10-5 system; International 10-10 system, Landmark

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Fiducial Marker

Definition: Fiducials are usually referred to as physical attachments, insertions, or digital markers, often positioned at well-defined locations with strong detectable signals in the acquired experimental data or auxiliary measurements. Fiducials are typically used for facilitating the localization of sensors and co-registration between probes and anatomical structures.

Alternative definition:

Synonym: Fiducial landmark, Fiducial

References: https://bids-specification.readthedocs.io/en/stable/04-modality-specific-files/11-near-infrared-spectroscopy.html

Related terms: Coordinate system, Vitamin E capsules, Digitizer

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Field of View

Definition: The field-of-view (FOV) is the extent of tissue that can be effectively captured by a certain fNIRS probe configuration. It determines the region that the optode array is sensitive to.

Alternative definition: (if applicable)

Synonym: Resolution

References:

Related terms: coverage area

Forward Model

Definition: The forward model (y = Ax, where y is the simulated or measurement data, A is the sensitivity matrix, and x is the changes in optical properties) for fNIRS describes the relationship between the changes in optical density measured by source-detector pairs on the scalp and the changes in optical properties in the underlying brain tissue. Photon migration is simulated for any given source and detector pair using a segmented head model, typically with 5 tissue types. The result is the so-called sensitivity matrix (A) or Jacobian matrix. The rows of the sensitivity matrix (A) represent each source-detector pair's sensitivity to the underlying absorption changes. This sensitivity matrix (A) can be used to solve the inverse problem in the Diffuse Optical Tomography image reconstruction process.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2009.07.033

https://doi.org/10.34133/2022/9850248

Related terms: Forward Problem, Inverse Problem, Diffuse optical tomography, Sensitivity matrix,

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Frame rate

Definition: Frequency at which frames are recorded in Hz.

Alternative definition:

Synonym: Temporal resolution

References:

https://doi.org/10.1117/1.nph.8.1.012101

Related terms: sampling rate, Nyquist frequency

General linear model

Definition: General linear model is a linear regression model that allows for analyzing data (γ) according to a given set of regressors often also referred to as predictors in the context of experiment design, (χ) by estimating fit coefficients (β). The general equation of the GLM is: $Y=X\beta + \varepsilon$. For fNIRS, γ is the time series of fNIRS measurements, χ is the design matrix including all regressors, β is the coefficients to be estimated for each regressor, and ε is the the error term which is assumed to be spherical Gaussian N(0,σ). The model is typically solved via generalized ordinary least squares: $ \beta = (X^TX)^{-1}X^TY $ $ cov(\beta) = (X^TX)^{-1} $ In order for this solution to be the best linear unbiased estimate of the coefficients, the Gauss-Markov assumptions have to be fulfilled, namely linearity, random sampling, non-collinearity, strict exogeneity and spherical errors.

Alternative definition:

Synonym:

References: https://doi.org/10.1007/978-1-59745-530-5_10

Related terms: Linear regression, Generalized Linear Mixed Model, regression

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Hemodynamic response function

Definition: A hemodynamic response function (HRF) is a transfer function that models the hemodynamic changes in response to neural activity. The shape of the HRF is mediated by several non-neuronal factors (e.g. hematocrit, size and density of the vasculature) and can vary depending on the nature of the neural activity, the brain region as well as individual differences (e.g. age, disease). The HRF models can be fixed such as double-gamma HRF model, or more flexible such as FIR, or consecutive gaussians. The basic parameters of these models are the width, latency and amplitude that determine the shape of the HRF.

Alternative definition:

Synonym:

References: https://doi.org/10.1006/nimg.1998.0369

https://doi.org/10.1007/s11682-020-00358-8

https://doi.org/10.1117%2F1.NPh.6.2.025009

https://doi.org/10.1016/j.neuroimage.2004.07.013

https://andysbrainbook.readthedocs.io/en/latest/fMRI_Short_Course/Statistics/03_Stats_HRF_Overview.html

Related terms: Hemodynamic response; Gamma distribution; FIR Deconvolution; Canonical HRF; BOLD response, neurovascular coupling

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High-pass filter

Definition: A high pass filter (HPF) allows the signal portion corresponding to high-frequency values alone to pass through it.

Alternative definition:

Synonym:

References: https://www.sciencedirect.com/topics/engineering/high-pass-filter

Implementation of Smart Healthcare Systems using AI, IoT, and Blockchain, 2023

Related terms: low-pass filter, filtering, preprocessing, low frequency oscillations, noise, bandpass filter

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Image Reconstruction

Definition: Image reconstruction in functional near-infrared spectroscopy (fNIRS) is the process of generating 2D or 3D spatially varying images of the hemodynamic response in the brain using recorded signals from fNIRS optodes on the scalp, typically using a head model as a spatial prior (either subject-specific or atlas-based), often referred to as Diffuse Optical Tomography (DOT). This is an approach for image reconstruction in fNIRS, which uses a computational model of light propagation within the head (forward problem) to estimate the distribution of hemodynamic changes that give rise to the measured signal (inverse problem). The forward problem and inverse problem are two important steps in image reconstruction. The forward problem refers to the calculation of the distribution of light propagation (Intensity, Phase, Time of Flight) in the head, given the distribution of the light sources and detectors on the scalp while the inverse problem refers to the estimation of the hemodynamic response in the brain tissue from the measured signal.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.8.1.012101

https://doi.org/10.1117/1.NPh.8.2.025010

https://doi.org/10.1364/OE.17.020178

https://doi.org/10.1117/1.JBO.22.12.125001

https://doi.org/10.1016/j.neuroimage.2013.03.069

https://doi.org/10.34133/2022/9850248

Related terms: Diffuse Optical Tomography, Forward problem, inverse problem

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Independent Component Analysis

Definition: Independent component analysis (ICA) is a blind source separation method which separates a multivariate data (e.g., fNIRS signal) into statistically independent components which are assumed to be statistically independent from each other and have a non-gaussian distribution. Different types of ICA are available (e.g. linear and non-linear ICAs). The removal of physiological noise (such as heart rate and respiration) and motion artifacts, as well as the identification of neuronal activity sources, have been demonstrated to be effectively achievable in fNIRS data using ICA.

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fninf.2021.683735

https://doi.org/10.1016/0165-1684%2894%2990029-9

https://doi.org/10.1109/embc.2013.6611118

https://doi.org/10.1098/rsta.2011.0534

https://doi.org/10.1063/1.4812785

https://doi.org/10.1016/j.neuroimage.2010.02.080

Related terms: Principal Component Analysis, Cocktail Party Problem, Central limit theorem, noise removal, functional connectivity

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Inverse problem

Definition: In the framework of the forward problem ($y = Ax$, where y is the simulated or measurement data, A is the sensitivity matrix, and x is the changes in optical properties), the goal of an inverse problem would be to reconstruct or infer the characteristics

of the original signal source (e.g, changes in hemodynamic activity in the brain) based on the measured signal (e.g., changes in optical intensity). This model is often expressed as an inverse operator or transform, which maps the unknowns to the observed data. However, due to the possibilities of multiple solutions or uncertainties, inverse problems often tend to be ill-posed.

Alternative definition:

Synonym:

References: https://doi.org/10.34133/2022/9850248

Related terms: Forward model, Forward problem, Inverse problem, Image Reconstruction

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Lab Streaming Layer

Definition: The lab streaming layer (LSL) is an open source software framework which allows exchanging data streams (e.g., time series data between programs and devices) in real time using a local network instead of a trigger cable. This streaming of time-series data (e.g. fNIRS, EEG) allows for multi-modal time-synchronization. LSL is supported by various NIRS hardware devices, acquisition programs as well as presentation softwares. The core transport library of LSL is liblsl and it is applicable to different language interfaces (C, C++, Python, Java, C#, MATLAB) and platforms.

Alternative definition:

Synonym:

References: https://doi.org/10.34133/2022/9850248

Related terms: real-time processing, multimodal time-synchronization

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Low-pass filter

Definition: Low-pass filters are used to keep signal frequencies below a certain frequency threshold by attenuating signals above this threshold. As low-pass filters remove high-frequency content of a given signal (e.g., cardiac oscillations or instrument noise) they have the effect of smoothing the signal.

Alternative definition:

Synonym:

References: Luck, S. J. (2014). An introduction to the event-related potential technique. MIT press.

Related terms: High-pass filter, Band-pass filter, preprocessing, noise

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Mixed-effects model

Definition: Mixed-effects model is a statistical model containing both fixed effects and random effects. In contrast to fixed effects, mixed effects models contain one or more random effects to each fixed effect, which can consist of random intercepts and random slopes. Equation of a mixed-effects model is given below: $ y = \chi \beta + Zu + epsilon $ y : The dependent variable or response variable being modeled χ: The design matrix of fixed effects β: Fixed-effect regression coefficients Z: The design matrix of random effects u: Random effects regression coefficients ϵ The residual error or noise in the model

Alternative definition:

Synonym: General Linear mixed models

References: https://doi.org/10.1007/BF00140873

Winter, B. (2019). Statistics for linguists: An introduction using R. Routledge.

https://doi.org/10.18637/jss.v067.i01

Seltman, Howard J. "Experimental Design and Analysis." (2018)

Related terms: High-pass filter, Band-pass filter, preprocessing, noise

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Motion artifact

Definition: Motion artifacts are changes in the signal caused by the movements of the subject being measured. In the context of fNIRS, one major cause of motion artifacts is the scalp-optode decoupling due to head or skin movement. Such a decoupling can cause high-frequency spikes in the signal if the optode recouples with the scalp at the same location, or it can create baseline shifts in the signal if the optode settles on a different location on the scalp after the motion. Motion artifacts can significantly reduce the quality of the fNIRS data making it challenging to estimate underlying hemodynamic changes.

Alternative definition:

Synonym: movement artifact, movement artifact, body movement, body artifact, optode movement

References:

Related terms: artifact correction, preprocessing, artifact, noise

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Motion correction

Definition: Motion correction refers to the strategy that corrects the data contaminated by motion artifacts. In fNIRS data analysis, two types of motion correction techniques are available: those that rely on a prior motion detection algorithm which typically requires parameter tuning, and those that correct motion artifacts in a fully automated manner.

Alternative definition:

Synonym: Motion removal, motion scrubbing, motion censoring, denoising

References:

fNIRS / DOT:

https://doi.org/10.1016/j.neuroimage.2013.04.082

https://doi.org/10.1117/1.NPh.5.1.015003

https://doi.org/10.1117/1.NPh.7.1.015001

https://doi.org/10.1088/0967-3334/33/2/259

https://doi.org/10.1002/hbm.25111

https://doi.org/10.1142/S1793545813500661

https://doi.org/10.1117/1.1852552

https://doi.org/10.1016/j.neuroimage.2019.116472

https://doi.org/10.1016/j.neuroimage.2019.06.056

https://doi.org/10.1088/0967-3334/31/5/004

fMRI:

https://doi.org/10.52294/apertureneuro.2022.2.nxor2026

https://doi.org/10.1002/hbm.24635

https://doi.org/10.1016/j.neuroimage.2005.05.058

https://doi.org/10.1073/pnas.1720985115

https://doi.org/10.1002/hbm.22307

https://doi.org/10.1016/j.neuroimage.2011.02.073 (infants)

Related terms: Artifact, Accelerometer, Gyroscope, Inertial measurement Unit (IMU)

Motion artifact identification

Definition: Motion artifact identification refers to the algorithms that are used to find data points in the fNIRS signals affected by motion artifacts. The available motion identification methods are typically based on detecting large variance in the fNIRS recordings e.g., data points exceeding a certain threshold of the standard deviation and/or amplitude of the fNIRS signal within a predefined time window. Motion identification algorithms generally require fine tuning the thresholds of signal variance.

Alternative definition:

Synonym: Motion artifact detection

References: https://doi.org/10.3389/fnins.2012.00147

Related terms: Artifact, Motion correction

Multi Distance

Definition: Multi distance refers to the use of multiple source-detector distances in a probe design.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.2.1.015003

Related terms: High Density (HD), Ultra High Density (UHD), Channel, Probe configuration, Short-distance channel, Long-distance channel

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Multi-channel

Definition: A multi-channel approach refers to the use of multiple emitters and detectors to simultaneously record brain activity across different loci. Multi-channel brain imaging techniques provide spatial maps of brain functions that are more informative compared to the single-channel approach.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.06.062

Related terms: Single-channel, Whole-head

Multiple Comparison Correction

Definition: Multiple comparison correction is a range of statistical procedures that allows one to take into account the fact that several statistical inferences are being performed simultaneously which increases the probability of observing a significant result just due to chance. An example would be a channel-wise comparison between two conditions or between two time points. When performing multiple statistical tests, the risk of increase in false positives known as Type 1 error is controlled by using multiple comparison correction procedures such as Bonferroni method, the False Discovery Rate (FDR) and Benjamini-Hochberg method.

Alternative definition:

Synonym: multiplicity problem

References: https://doi.org/10.1016/j.neuroimage.2006.06.047

https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Related terms: Bonferroni, FDR

Noise

Definition: Noise is any unwanted component(s) of the signal that masks the signal aimed to be captured, and/or reduces the quality of the signal aimed to be captured. It could originate from different sources such as physiological sources (e.g., due to cardiac and respiratory activity), motion (e.g., due to head movement), environment (e.g., sunlight), hardware (e.g., due to fluctuations in the light sources), or even experimental design and modeling (e.g. from assumptions).

Alternative definition:

Synonym:

References: https://doi.org/10.1088/0031-9155/55/13/009

https://doi.org/10.1109/PROC.1967.5700

https://doi.org/10.1002/0470841621.ch2

https://doi.org/10.3389/fnins.2020.00724

https://doi.org/10.1063/1.4812785

Related terms: physiological noise, systemic noise, instrument noise, artifact, motion artifact, uncertainty, residuals

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Noisy channels

Definition: Noisy channel refers to a fNIRS channel of insufficient signal quality (i.e. signal-to-noise ratio) that may not or hardly allow to reliably examine hemodynamic activity. Noisy channels can be caused by several factors, including an insufficient light-tissue coupling, defects in the hardware components (e.g. optodes,cables, electrical circuits), or movement artifacts. In fNIRS signal processing, noisy channels are identified by either manual, semi-manual or automatic methods (e.g. by identifying noisy channels through exceeding a specific threshold of the standard deviation of the signal).

Alternative definition:

Synonym: aberrant channels, noisy channels

References:

https://doi.org/10.1364%2FBOE.7.005104

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: scalp coupling index, peak spectral power, coefficient of variation, spikes, baseline shifts, signal quality, signal calibration, scalp-optode coupling

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Non-causal Filter

Definition: A non-causal filter is a type of filter that depends not only on past and present time points but also integrates information of future time points of a given signal. This is in contrast to causal filters, which only use past and present samples to filter a signal. A typical implementation of a non-causal filter is a zero-phase filter which suppresses distortions such as phase delays which are

commonly introduced by causal filters. Zero-phase filters are typically implemented by running a causal filter forward and backward over the data.

Alternative definition:

Synonym: Acausal filters, zero-phase filter

References:

https://doi.org/10.1016/j.neuron.2019.02.039

https://doi.org/10.1016/j.jneumeth.2012.06.011

Related terms: Causal filter, filtering, data preprocessing

Peak Spectral Power

Definition: Peak spectral power (PSP) is a measure of the amplitude or strength of a frequency component that is most prominent in a particular frequency range or spectrum. Data, e.g. time series, images, etc, can be decomposed into spectral power by applying transformations such as the Fourier Transform. Within a pre-defined frequency band, spectral peak power can be detected. In the context of fNIRS signal quality assessment, the PSP is computed to complement the scalp coupling index in order to enhance signal quality assessment.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.8.4.041001

Related terms: Peak Spectral Density, data quality assessment, scalp coupling index

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Pre-coloring

Definition: Pre-coloring replaces unknown fNIRS signal autocorrelation with autocorrelation of a known form. This involves the use of temporal smoothing with a smoothing kernel of known correlation structure. The reason for precoloring is to enforce that the signal complies with the assumption of the model that is used for statistical inference. For instance, the ordinary least squares solution to the general linear model assumes that the residuals are serially independent. If the residuals are serially dependent - as in the case of the fNIRS signal due to e.g. physiological fluctuations-, however, this will result in the underestimation of estimates of parameter standard deviations and thus overestimation of statistical significance. Please note that, precoloring, if not used properly, can lead to an overestimation of the true effect.

Alternative definition:

Synonym:

References: https://doi.org/10.1002/1097-0193(200102)12:2%3C61::AID-HBM1004%3E3.0.CO;2-W

https://doi.org/10.1117/1.nph.3.1.010401

https://doi.org/10.1016/j.neuroimage.2008.08.036

Related terms: Pre-whitening, noise, GLM

Pre-processing

Definition: Pre-processing refers to the various steps that transform the data prior to analysis (i.e. prior to e.g. general linear model or image reconstruction). Pre-processing of fNIRS data usually aims at reducing noise in the signal, such as motion artifacts and systemic physiology components.

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fnhum.2018.00505

https://doi.org/10.1016/j.dcn.2021.100943

Related terms: noise, filtering, signal quality, artifact, SNR

Pre-whitening

Definition: Pre-whitening is a technique used to eliminate autocorrelations from residuals in preparation for analysis with the General Linear Model (GLM), which is essential for fNIRS signals characterized by $\frac{1}{f}$ noise—where noise power inversely correlates with frequency (f). This process involves applying a whitening filter W to make the noise distribution uniform, thereby minimizing errors in statistical models like GLM and reducing the False Discovery Rate. The whitening matrix W is derived iteratively by fitting the GLM, analyzing residuals, and estimating W through an autoregressive (AR) model fitted to these residuals. This model adjusts for noise structure by accounting for autocorrelation in the data, and its coefficients are used to construct W. The efficacy of W in reducing autocorrelation depends on the order of the AR model, which specifies the extent of autocorrelation it can address.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.jbo.22.5.055002

https://doi.org/10.1002/1097-0193(200102)12:2%3C61::AID-HBM1004%3E3.0.CO;2-W

DOI:10.1364/BOE.4.001366

Related terms: noise, pre-colouring, General Linear Model

Principal component analysis

Definition: Principal component analysis is a vector space transform that operates by transforming a set of correlated variables into a new set of uncorrelated and orthogonal variables called the principal components. The principal components are ordered in terms of the variance they explain. That is, the first principal component represents, for a single dimension (i.e., a single variable), the greatest amount of variability in the original data set. Each subsequent orthogonal component accounts for as much of the remaining variability as possible subject to the required orthogonality. A common use for PCA is dimensionality reduction and/or filtering whereby subsequent to PCA, some of the components in the new coordinate bases are sacrificed. In fNIRS analysis, PCA has been applied to address operations both during processing and analysis, e.g. for motion artifact correction, assuming that the greatest variance in the signal is explained by artifacts.

Alternative definition:

Synonym:

References:

https://doi.org/10.1201/9780203024058

Related terms: Motion Artifact Correction, Preprocessing, Factor Analysis, Noise

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Raw data

Definition: Raw data is the unprocessed acquired data. For fNIRS systems, it refers to the light intensity (I) data.

Alternative definition:

Synonym:

References:

Related terms: data acquisition

Real-time

Definition: Real-time defines that the acquisition and processing of data occurs during the recording within a relatively short period of time. Although the term ‘real-time’ is used very frequently, these processes never actually take place in real-time, but only take place in batches of data. With a small batch size, these processes are perceived as real-time. In fNIRS, batch processing can be found, for instance, in some recording softwares (e.g., real-time channel quality assessment) or in the context of applications such as fNIRS-guided neurofeedback and brain computer interfaces.

Alternative definition: Real-time refers to the operations applied to the data -i.e., the acquisition, processing, and if appropriate, analysis- that occur within the time lapse between consecutive samples acquisition.

Synonym: online

References: https://doi.org/10.1117%2F1.NPh.4.4.041504

https://doi.org/10.3389/fnins.2020.00346

https://doi.org/10.3389/fnhum.2020.00113

Related terms: Neurofeedback, Brain Computer Interfaces, Lab Streaming Layer

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Registration

Definition: Registration is the process of spatially registering, i.e. matching, fNIRS optode locations on the head surface to an anatomical representation, including 3D images or meshes derived from the subject’s volumetric MRI, or an MRI atlas such as Talairach Atlas, MNI152 or Colin27. It is commonly called co-registration if the anatomical representation is the subject's volumetric MRI. Registration allows for estimating the spatial location of brain activities or anatomical features and correlating with the signals probed by spatially distributed channels, assisting the interpretation of the observed brain activities in the context of brain anatomy. There are a number of algorithms to perform this procedure, such as rigid-body based least-square fitting and iterative closest point (ICP) based approaches.

Alternative definition:

Synonym: Spatial registration, Optode registration

References: https://doi.org/10.1016/j.neuroimage.2013.07.025

https://doi.org/10.1109/TMI.2007.892508

https://doi.org/10.1117/1.JBO.20.1.016009

Related terms: 3D-Digitizer, 10-20 System, MNI template, head modeling

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Reverse Inference

Definition: Reverse inference is a method of drawing conclusions about cognitive processes from an observed brain activation. An example of reverse inference would be claiming 'brain area X is active, therefore these participants are engaged in cognitive process Y'. One should be cautious drawing such a conclusion as a brain region can be responsible for multiple processes.

Alternative definition:

Synonym: Abductive reasoning

References: https://doi.org/10.1016/j.tics.2005.12.004

https://doi.org/10.1016/j.conb.2008.07.006

https://doi.org/10.1007/s11229-022-03585-2

https://doi.org/10.1016/j.neuron.2011.11.001

Related terms: Forward inference

Scalp coupling index

Definition: Scalp coupling index (SCI) is a signal-to-noise ratio measurement computed as the zero-lag cross-correlation between the normalized raw intensity signals at two wavelengths, filtered in the cardiac frequency band. In fNIRS analysis, the SCI is applied in the context of signal quality assessment on a channel-by-channel basis. Channels below a certain, pre-defined threshold are thus classified as channels with insufficient data quality and excluded from further analysis.

Alternative definition:

Synonym:

References:

https://doi.org/10.1364%2FBOE.7.005104

Related terms: Signal Quality Assessment, Peak Spectral Power

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Sensitivity

Definition: The sensitivity or true positive rate is defined as the probability that a statistical test will be positive for a true statistic .

Alternative definition:

Synonym:

References:

http://mathworld.wolfram.com

Related terms: Specificity, receiver operating characteristic (ROC) curve, Performance

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Sensitivity matrix

Definition: The sensitivity matrix maps local absorption changes within the brain to variations of optical density changes measured by each channel. It is typically represented as a matrix with rows corresponding to the channels of the fNIRS system and columns corresponding to the voxels (or surface elements) in the head. The accuracy of the sensitivity matrix depends on various factors, such as the geometry and spacing of the fNIRS probes, the optical properties of the tissue being measured, and the assumptions made in the model used to estimate the matrix.

Alternative definition: (if applicable)

Synonym: Jacobian

References:

http://mathworld.wolfram.com

Related terms: Sensitivity Map; A matrix, Jacobian

Signal

Definition: Signal is the variation of a form of energy over space or time. In fNIRS, the term can be used interchangeably for the raw intensity, optical density or hemoglobin concentration changes in time.

Alternative definition:

Synonym:

References:

DOI: 10.1108/00242530910928942

Related terms: hemodynamic response

Signal change

Definition: Signal change is the difference in signals between two or more measurements. For instance, the observed difference in HbO2 between conditions A and B, or time one vs time two are commonly referred to signal change.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2013.06.016

Related terms:

Signal noise ratio

Definition: Signal to noise ratio is the ratio of useful information from a system to that of an interfering unwanted, often random, information that is also present.

Alternative definition:

Synonym: signal to noise ratio

References: https://doi.org/10.1016/j.neuroimage.2013.06.016

Related terms: contrast to noise ratio (CNR), coefficient of variation (CV)

Shared near-infrared file format (.snirf)

Definition: The Shared Near Infrared File Format (SNIRF) is a standardized file format based on the Hierarchical Data Format (HDF5) used for organizing, storing, and sharing Near-Infrared Spectroscopy data and associated metadata. This format facilitates the exchange and analysis of fNIRS data across different hardware and software platforms. SNIRF is compatible with a variety of fNIRS analysis toolboxes and software platforms. It is designed to encapsulate various types of information, including metadata about the measurement, NIRS data, stimulus or trigger data, information about the probe set used, and any auxiliary data. The adoption of the SNIRF format helps streamline data sharing and collaboration within the fNIRS research community.

Alternative definition:

Synonym:

References: https://github.com/fNIRS/snirf

https://doi.org/10.1117/1.NPh.10.1.013507

Related terms: BIDS, Open Science, Open Data

Source Localization

Definition: Source localization is a technique used to determine the location of the neural generators that give rise to a particular brain signal, such as an electroencephalogram (EEG) or magnetoencephalogram (MEG) signal. In addition, use of fNIRS for source localization measures changes in blood oxygenation in the brain as an indirect measure of neural activity that can be used as prior information in solving the inverse problem. The importance of source localization is the understanding of the neural mechanisms underlying cognitive processes and provide insights into the different techniques that can be used for this purpose.

Alternative definition:

Synonym:

References: https://github.com/fNIRS/snirf

https://doi.org/10.1117/1.NPh.10.1.013507

Related terms: BIDS, Open Science, Open Data

Spatial resolution

Definition: Refers to the minimum image size of an ideal point source and therefore reflects an imaging system's ability to accurately reproduce the contrast available in the object. It is usually specified in terms of the point spread function (PSF) or line spread function (LSF), or by the modulation transfer function (MTF), which is the frequency space representation of the PSF. Both of these concepts assume that the imaging system is linear and stationary, which is not generally the case. Spatial resolution is often measured in two orthogonal directions: in-plane ($x-y$) and cross-plane (z)

Alternative definition:

Synonym:

References:

J. Hsieh. Computed Tomography: Principles, Design, Artifacts, and Recent Advances. SPIE Press monograph. SPIE Press, 2003.

Related terms:

Spikes

Definition: Spikes are signal features characterized by a sudden change much larger in magnitude than changes in the surrounding signal. In fNIRS, spikes are a common manifestation of optode movement artifacts.

Alternative definition:

Synonym:

References:

https://doi.org/10.1109/EMBC46164.2021.9631014

https://doi.org/10.3389/fnins.2012.00147

Related terms: baseline shifts, artifact, Motion Artifact Correction, Preprocessing

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Statistical Parametric Mapping

Definition: Statistical Parametric Mapping (SPM) is an analysis technique used in functional neuroimaging to identify regions of brain activation related to an experimental task. This is quantified as a parametric map -a voxel-wise collection of statistical values

(typically beta- or t-values) obtained using the general linear model (GLM) framework. The term SPM also refers to a free MATLAB toolbox developed at Wellcome Centre for Human Neuroimaging that implements preprocessing and modeling functionality that can be used to generate statistical parametric maps.

Alternative definition:

Synonym:

References:

https://doi.org/10.1002/hbm.460020402

Related terms: General Linear Model

Systemic physiology augmented functional near-infrared spectroscopy

Definition: Systemic physiology augmented functional near-infrared spectroscopy (SPA-NIRS) is a method that uses fNIRS data in combination with the measurement of systemic physiological activity (e.g., cardiorespiratory and autonomic activity) to (i) improve the physiological interpretation of fNIRS measurements, (ii) use the systemic physiological signals to regress them out from fNIRS data, and to (iii) gain novel insights into the complex interplay of the brain with the physiological state of the entire body.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.9.3.030801

Related terms: Preprocessing, Short-distance channel

Temporal resolution

Definition: Temporal resolution is defined as the amount of time needed to revisit and acquire a new observation from the exact same location.

Alternative definition:

Synonym:

References:

https://doi.org/10.5860/choice.45-5931

Related terms: Sampling frequency, Sampling rate

Time Frame

Definition: Time frame typically refers to a discrete time interval (usually in seconds or milliseconds) over which a set of optical measurements are acquired. Each frame is divided into a series of smaller time intervals called "time bins" or "data points" and the optical signal is sampled at a fixed sampling rate during each time bin.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.nph.8.1.012101

Related terms:

Time series

Definition: Time series is a sequence of data points ordered in time. Typically, the parameter/variable is sampled at regular time intervals, δt , which defines a sampling frequency, f_s given by $ f_s = \frac{1}{\delta t}$. For instance, in fNIRS, the intensity detected at a detector coming from a light source defines a time series for the light intensity at a source-detector pair.

Alternative definition:

Synonym:

References: https://doi.org/10.1145/2379776.2379788

https://doi.org/10.1201/9781420036206

Related terms: Time courses; Sampling frequency, Signal, Time points, Statistical Analysis, Channel

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Time window

Definition: A time window refers to a specific period in the dataset during which the recorded data is analyzed. The length of the time window depends on the research question and the nature of the experiment. The analysis of fNIRS data is often conducted by dividing the entire recording period into several time windows, typically several seconds long. During each time window, the signal is processed and analyzed to identify metabolism in the brain. The choice of the time window is an essential consideration in fNIRS analysis, as it can affect the sensitivity and specificity of the results.

Alternative definition: In the context of time-domain fNIRS, the time window refers to the duration of the measurement period during which the photons are detected and used to calculate the optical properties of the tissue.

Synonym:

References: DOI: 10.1109/ICA-SYMP.2019.8646261

Related terms:

Topological Analysis

Definition: Topological analysis refers to processing and analytical approaches that leverage the field of mathematical topology; i.e. the study of bicontinuous deformations. In fNIRS, the so-called topographical plots exploit the natural topology of the sampling lattice yielded by the channel locations. Other uses in fNIRS thus far included dimensionality reduction efforts, segregational and intergenerational analysis.

Alternative definition:

Synonym: Network-based Analysis, Connectivity Analysis

References:

https://doi.org/10.3389/frai.2021.667963

https://doi.org/10.1117/1.NPh.5.1.011011

https://doi.org/10.1117/1.NPh.7.4.045009

Related terms:

Topographic map

Definition: A topographic map is a two-dimensional graphical representation. For example, in the context of fNIRS, this could be the spatial distribution of channel sensitivities, hemodynamic response or effect size projected on a 2D surface.

Alternative definition: (if applicable)

Synonym:

References:

Related terms:

Virtual registration

Definition: Virtual registration is a form of registration that is based on anchoring fNIRS optode or channel locations to an International 10-20 reference point and as such does not require the 3D digitization of the optode locations.

Alternative definition:

Synonym:

References:

Related terms: Spatial normalization; Image registration; registration; co-registration

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Visual Inspection

Definition: Visual inspection refers to the subjective process of checking fNIRS signal quality online or offline in order to evaluate the quality of the signal. Visual inspection is a form of data quality inspection. While this form of inspection is inherently subjective due to not being based on objective criteria, it taps on the experimenter experience and can be useful when detecting noisy channels during pre-acquisition or motion artifacts during data processing.

Alternative definition:

Synonym:

References: not applicable

Related terms: Quality check, Data quality assessment, Preprocessing , Noisy channels, Artifact, Spikes, Noise, Baseline drift

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Wavelet transform

Definition: Wavelet transform (WT) applies an orthogonal kernel to provide a transformation from time space to time-scale space that can be either performed in a discrete or continuous fashion. Note that the term time here is not intended in the physical sense, and can refer to other sampling lattices, for instance, images. By translating and dilatating the kernel, termed the mother wavelet, the wavelet transform provides a time-scale representation of the input data that often facilitates downstream analysis such as spectral analysis or to calculate connectivity estimators. There are many wavelet transforms as well as many mother wavelets with different virtues and assumptions. For instance, the discrete wavelet transform (DWT) performs the dilatation in a less fine-grained resolution as compared to the continuous wavelet transform but it is computationally faster. Wavelets have proved popular in fNIRS for filtering and denoising (e.g. motion artifacts), hyperscanning coherence analysis, or the interpretation of connectivity among others.

Alternative definition:

Synonym:

References: https://doi.org/10.1175/1520-0477(1998)079%3C0061:APGTWA%3E2.0.CO;2

Related terms: Functional Connectivity, Motion Artifact Correction, Time-Frequency Analysis, Preprocessing, Filtering, Multiresolution Analysis

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Wavelet coherence

Definition: Wavelet coherence is a method commonly used in hyperscanning studies to quantify the relationship between brain activity in two participants. Data for each participant is subject to a wavelet transform which provides a time-scale representation of that channel. The wavelet representations can then be related across participants to calculate the wavelet coherence. If stronger wavelet coherence is seen in true dyads compared to pseudo-dyads (when data from non-interactive participants is paired up), then there is a coherence effect.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2011.09.003

Related terms: Time-Frequency Analysis, Hyperscanning, Multiresolution Analysis

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Wiener Filter

Definition: The Wiener filter is an MSE-optimal stationary filter that uses nonlinear equations for IIR filters or linear equations for FIR filters to estimate a desired output from an observed noisy signal. The underlying assumption is that the signal and noise are stationary and uncorrelated. Popular uses of Wiener filters are denoising, deblurring and upsampling.

Alternative definition:

Synonym:

References:

https://doi.org/10.1109/TBME.2005.845243

Related terms:

Baseline

Definition: Baseline (BL) refers to the participant's physiological state at a resting or non-stimulated state recorded before performing an experimental task or perceiving stimuli. In the context of fNIRS, it reflects the neurophysiological state (e.g., brain activity) measured when the participant is at rest or not receiving any stimulation. The baseline period can refer to the resting state before an experimental task begins, but also to periods of rest before a new task block or stimulus is presented.

Alternative definition:

Synonym:

References: Eddie Harmon-Jones and Jennifer S Beer. Methods in social neuroscience. Guilford Press, 2012.

Related terms: Baseline period

Baseline period

Definition: Baseline period refers to a segment of time preceding the measurement in an experiment, used to establish a reference or comparison point. In fNIRS, the duration of this segment is typically few to several seconds before the onset of an experimental task.

Alternative definition:

Synonym:

References: https://doi.org/10.1007/978-3-319-39955-3_34

Related terms: Baseline, Block Design, Event-related design

Between-participant design

Definition: A between-participant design is a type of experimental design in which participants are allocated to independent experimental or treatment groups (including the control group). The main purpose of this study design is to examine the difference between groups. Participants may be separated into groups based on their characteristics (e.g., children with ADHD vs. healthy controls). Random assignment to two groups is also possible. If assignment is random, the study allows for causal conclusions.

Alternative definition:

Synonym: Between-group design, Between-subject design, independent measures design

References: N/A

Related terms: Within-group design, Within-subject design, Within-participant design; Experimental design, ANOVA

Block design

Definition: A block design is a type of experimental paradigm in which trials belonging to the same experimental condition are arranged in blocks (i.e., grouped together), with blocks usually separated by a rest period. The original purpose of a block design is to increase the signal-to-noise ratio (SNR) and to reduce the effects of variability within individual trials.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.8.2.025008

https://doi.org/10.1192/apt.bp.115.015610

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Event-related design, Experimental Run, Experimental Session, Experimental paradigm, Trial

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Cap size

Definition: Cap size is the size or dimensions of the fNIRS cap that is worn on the participant's head. When selecting a cap size for fNIRS measurements, it is important to consider factors such as the population being studied and head size/shape variations.
Category:

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2014.11.022

Related terms: Head size, Headband, Head circumference

Channel

Definition: A channel is a measurement point that the system is capable of recording from. In the special case of fNIRS, a channel is defined as the area between a light source and a detector, and is often visually depicted as the midpoint of the two and at a depth of approximately half of the source-detector distance. The source-detector distance categorizes a channel as a typical long-separation fNIRS channel (reflecting cortical activation changes and changes in systemic physiology) or a short-separation/short-distance channel (primarily reflecting changes in skin perfusion).

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.8.1.012101

https://doi.org/10.1192/apt.bp.115.015610

Related terms: Optode, Detector, Emitter, Optode template, Montage, Optode configuration, Short-separation channel, Short-distance channel

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Counterbalancing

Definition: Counterbalancing is a method utilized to mitigate order effects in repeated measures designs. In this procedure, when the experimental paradigm involves multiple conditions, the participant group is divided into sub-groups with equal numerosity. Each sub-group experiences the various conditions in different sequences, whether it be two or more, to avoid the presence of systematic order effects.

Alternative definition:

Synonym:

References: https://doi.org/10.1002/9781118445112.stat06195

https://doi.org/10.1037/a0029310

Related terms: Latin Square Design, Randomization

Dyad

Definition: In the context of an fNIRS experiment, a dyad refers to two individuals that participate in an experiment together, typically interacting with each other (e.g., parent-child dyad).

Alternative definition:

Synonym: Pair

References: https://doi.org/10.2307/351453

https://doi.org/10.1111/nyas.13948

Related terms: Hyperscanning

None

Definition: In experimental designs, jitters refer to the introduction of (pseudo-) random variations in the timing between successive stimulus onsets. They are implemented to mitigate potential confounds (e.g., habituation effects), avoid inducing rhythmic or predictive brain responses that are time-locked to the periodic onset of stimuli, and assist in deconvolving the hemodynamic response by introducing stimulus timing variability. Moreover, jitters are introduced to minimize temporal autocorrelation and enhance statistical power. That is, they serve to reduce correlation between successive stimulus onsets, mitigating any potential bias caused by temporal dependencies. By introducing (pseudo-) random variability in the timing of stimuli, jitters can help to improve the reliability and robustness of statistical analyses.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1002/(SICI)1097-0193(1999)8:2/3<109::AID-HBM7>3.0.CO;2-W

https://doi.org/10.1162/jocn.2008.20007

Related terms: Stimulus Onset Asynchrony (SOA), Inter-stimulus interval (ISI), Inter-trial interval (ITI)

Event-related design

Definition: Event-related design is a type of experimental paradigm in which trials are presented randomly or in a pseudo-random order, with each trial consisting of a single presentation of the stimulus or event. Compared to block designs, event-related designs provide greater temporal resolution and allow for more variability in the timing and order of the events. For instance, cognitive adaptation strategies of the subjects can be avoided, the response profile for different trial types (and even single trials) can be estimated by event-related averaging and it allows post-hoc sorting of individual brain responses.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/S0896-6273(00)80456-0

https://doi.org/10.1192/apt.bp.115.015610

https://doi.org/10.1016/j.jneumeth.2014.07.011

https://doi.org/10.1016/j.neuroimage.2005.12.008

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Block design

Experimental design

Definition: The design of an experiment involves planning a set of procedures to examine a scientific hypothesis in terms of the relationship between independent and dependent variables. Thereby, the independent variable(s) is/are manipulated and effects on the dependent variable(s) are assessed (i.e., measured).

Alternative definition:

Synonym:

References: Roger E Kirk. Experimental design. Wiley Online Library, 1982.

Related terms: Event-related design; Block design; Between-participant design; Within-participant design

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Experimental paradigm

Definition: An experimental paradigm incorporates the presentation and response format of a certain task relevant to the research question. An experimental paradigm provides a structured approach to conducting research, ensuring that the study is rigorous, replicable, and meaningful.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.4324/9780367808280

https://doi.org/10.1002/hbm.460020402

Related terms: Task

Experimental Run

Definition: An experimental run refers to a single continuous period of data acquisition on a single participant. A study can consist of multiple runs collected on the same day (e.g., one per experimental task), or within several days/weeks in a longitudinal study.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2004.08.001

https://doi.org/10.1371/journal.pone.0159959

Related terms: Experimental Session

Experimental Session

Definition: An experimental session refers to all the experimental runs collected in a study from one participant at a particular time of the day, without removing data collection equipment. In within-subject designs, multiple experimental sessions can take place at different time points (e.g., longitudinal, intervention studies or different experimental conditions or experimental runs).

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1364/AO.48.00D280

Related terms: Experimental Run

Experimental Trial

Definition: An experimental trial is the smallest unit of an experimental task and contains a sequence of one or more stimuli. Trials are repeated a certain number of times in an experiment with the same or different stimuli belonging to the same or different conditions with a certain timing.

Alternative definition:

Synonym:

References:

Related terms: Event, Stimulus sequence, Inter-trial interval, Inter-stimulus interval

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Finger tapping

Definition: Finger tapping refers to a task where participants are instructed to rhythmically tap their fingers in a controlled manner. In a finger-tapping task, participants are instructed to touch their thumb with each of the other fingers of the same hand, sequentially. It can also refer to periodically tapping on a surface, commonly using the forefinger. Finger tapping can be self-paced or externally paced. Finger tapping is generally used to measure motor activity in order to test whether the fNIRS system records proper hemodynamic response or not or to locate the motor cortex.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2011.08.095

https://doi.org/10.1117/1.NPh.5.1.011006

https://doi.org/10.1016/j.neuroimage.2020.117597

https://doi.org/10.1016/j.jneumeth.2020.108790

https://doi.org/10.1038/s41598-023-33780-1

Related terms:

Frequency encoding/tagging

Definition: An experimental design and data analysis method in which a stimulus is presented at a specific frequency, and the measured brain (or other) responses are assessed for whether they exhibit oscillations / periodic responses at the stimulation frequency stimulus. Multiple stimuli can be studied simultaneously by presenting them at different frequencies. To minimize overlap in the frequency spectrum and avoid inference from systemic variables (e.g., heart rate, respiratory oscillations), prime numbers are often chosen as stimulation frequencies. This design is often used with techniques providing high temporal resolution such as EEG/MEG.

Alternative definition:

Synonym: Frequency tagging

References: https://doi.org/10.1523/JNEUROSCI.16-13-04207.1996

Related terms:

Head circumference

Definition: The measurement (usually in cm) of a participant's head diameter at the level of the nasion (the midpoint between the eyes, just above the nose bridge), the inion (the external occipital protuberance at the base of the skull) and the tragi (cartilage at the ear entrance) of the ears. Head circumference is usually assessed with a tape measure and is crucial for selecting the correct cap size for the participant. This information can also be used in head modeling processes.

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1117%2F1.NPh.7.3.035008

Related terms: Head size, Head model, Cap size

Head size

Definition: Head size in fNIRS research is mostly described by the head circumference (in cm), as measured by wrapping a measuring tape around the head at the level of the nasion in the front, the inion at the back, and the left and right preauricular points (tragi). Head size is needed to choose the best-fitting cap size for the participant to ensure good contact between the optodes and the scalp. Head sizes vary depending on age, gender, and ethnicity. Adults' average head circumference ranges between approximately 52-58 cm (20-23 inches). For infants, head circumferences range between from 32-48 cm (13-19 inches) in the first year of life (for infants born full term) and increase to about 52-56 cm (20-22 inches) by adolescence.

Alternative definition:

Synonym:

References: ISO 7250: Basic human body measurements for technological design

Related terms: Cap size, Head circumference, Landmark, Headgear

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Hyperscanning

Definition: The simultaneous recording of brain activity from more than one person. Typically, a hyperscanning setup is used when the relationship between the participants' brain activities is of interest, thus during hyperscanning studies the participants are able to communicate with one another either verbally or non-verbally, for example by being in the same room or by seeing each other's actions.

Alternative definition:

Synonym: dyadic-brain recordings or multiple-brain recordings, Two-person Neuroscience

References: https://doi.org/10.1016/j.neuron.2020.11.008

https://doi.org/10.1006/nimg.2002.1150

https://doi.org/10.3389/fnhum.2020.00039

Related terms: Dyad; Inter-brain synchrony, Brain-to-brain coupling, Interpersonal neural synchrony (INS)

Inter-stimulus interval

Definition: Inter-stimulus interval (ISI) is the time period between the offset of one stimulus (S1) and the onset of the next stimulus (S2). The interstimulus interval can be fixed or jittered. If the duration is fixed, the ISI will last the same amount of time across trials; conversely, if the duration is jittered, the duration of the trial can (pseudo-) randomly vary within a fixed range.

Alternative definition:

Synonym: Inter-item interval

References: https://doi.org/10.1016/j.bandc.2005.11.009

Related terms: Inter-trial interval (ITI), inter-block interval, Stimulus onset asynchrony (SOA), Jitter

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Inter-trial interval

Definition: The inter-trial interval (ITI) is the time between two consecutive trials. It is measured from the onset of one trial to the onset of the next trial.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2008.05.013

Related terms: Inter-stimulus interval, Inter-block interval

Landmark

Definition: A landmark defines the location or a point defining an anatomical position on the human head. In the context of functional near-infrared spectroscopy (fNIRS), a landmark refers to a specific, easily identifiable anatomical point on the human head. Landmarks such as the preauricular points, nasion, inion, and Cz are used to accurately position the optodes and align fNIRS data with other neuroimaging data or estimate which cortical areas are covered by an fNIRS channel in terms of spatial registration. This ensures consistent measurements across individuals and studies.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.07.025

https://github.com/fNIRS/snirf/blob/master/snirf_specification.md#nirsiprobelandmarkpos2d

Related terms: EEG 10-20 System, Spatial registration, 3D digitizer

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Montage

Definition: A montage is the specific arrangement of the optodes (i.e., sources and detectors) placed on the scalp. The montage determines how sources and detectors are combined to form measurement channels. A montage can be customized to cover specific regions of interest by describing the arrangement of optodes according to a standard positioning system (e.g., the international 10-20, 10-10, and 10-5 systems, MNI space) or in relation to cranial landmarks (i.e., nasion, inion, left and right preauricular point). Montages are displayed in figures within manuscripts and are used as both visualizations and guides for confirming the locations of the optodes according to a standard positioning system.

Alternative definition:

Synonym: Optode template, Probe layout, Probeset, Probe set, Optode array design, Optodes configuration, Topographic layout

References: https://doi.org/10.1038/s41598-018-21716-z

https://doi.org/10.1117/1.JBO.19.2.026010

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Optode array, Optode template, Tomography, Topography, Coordinates, Regions of interest (ROI), Standard positioning system, Source, Detector

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N-back

Definition: The n-back task is a working memory paradigm where a sequence of stimuli in a chosen modality (e.g. visual) is presented (e.g. letters). Participants are asked to respond (e.g. via button press) when the currently presented stimulus is the same as the one presented n (usually 1, 2 or 3) trials before. For instance, in a 3-back task, where the trials consist of squares, participants have to decide whether the current square is the same as the square in trial n-3. With higher n, the working memory requirements increase. N-back tasks are usually presented in a block design, with e.g. 2-back working memory blocks and 1-back control blocks presented in (pseudo-) randomized order. The task requires several cognitive mechanisms such as encoding and temporary storage of each stimulus of the sequence. Incoming stimuli must be continuously updated while inhibiting irrelevant items, which must be removed from the working memory storage. It is also necessary to include a counting and matching process between the anticipatory and stored stimuli to make a decision as to indicate if the stimuli matches the correct response.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/0013-4694(93)90119-G

https://doi.org/10.3389/fpsyg.2018.02208

Related terms:

Pseudorandomization

Definition: The process of setting up an order of experimental trials/runs/sessions/conditions or an assignment of participants to specific (sub-)groups or treatments that is randomized, but with setting specific restrictions due to experimental considerations or subgroupings (i.e., not every order or assignment is possible). For example, when trials of the same condition should not be presented three times in row, one might choose an order that fulfills this condition, but is otherwise random. This process functionally approximates randomness, but is not completely random, as it excludes those orders that could have been generated randomly, but that show unwanted systematicity.

Alternative definition: (if applicable)

Synonym:

References:

Related terms: Quasirandom, Randomization

Randomization

Definition: Randomization is the process of setting up a random, i.e. accidental or arbitrary, order of experimental trials/runs/sessions/conditions or an assignment of participants to specific (sub-)groups or treatments without restrictions (i.e., every order or assignment is possible). If randomization follows specific rules or is limited by specific restrictions, then it is pseudorandomization (i.e., not every order or assignment is possible).

Alternative definition: (if applicable)

Synonym:

References:

Related terms: Pseudorandomization, Quasirandom

Region of interest

Definition: Particular regions of interest (ROI) of the brain that are defined when performing a fNIRS measurement (i.e. targeting only specific brain regions) or when analyzing the fNIRS data.

Alternative definition:

Synonym: Imaging Region of Interest

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1038/s41598-018-21716-z

https://academic.oup.com/scan/article/2/1/67/2362895

Related terms: Optode template, Montage

Reaction time

Definition: Reaction time (RT) is the time elapsing between stimulus presentation (e.g., stimulus onset or some other relevant time point during stimulus presentation) and the registered onset of the participant's behavioral response (e.g., via a button press). In fNIRS experiments, reaction times are often used as additional behavioral measurements to examine links between brain and behavior.

Alternative definition: (if applicable)

Synonym: Response time

References:

Related terms: Performance, Accuracy, Response speed

Rest period

Definition: Rest period refers to the intervals of time during an experimental task when the participant is not performing any task or processing stimuli. In experimental designs, rest periods often separate different blocks of an experimental task. During rest, baseline or resting state activation is being measured, and is typically used as a comparison for analyzing brain activation during a task or stimulation.

Alternative definition:

Synonym: Resting period

References: https://doi.org/10.3389/fnhum.2018.00505

Related terms: Task period, Baseline, Baseline period

Resting state

Definition: Resting state is a condition of a participant's nervous system and empirical measurements thereof (e.g. with MRI, NIRS or EEG) in which no explicit external stimulation or task is given or presented. Several different brain networks, such as the default mode network, are believed to be active in this condition. Measuring resting state brain activity or connectivity is often used to establish differences between groups of participants (e.g. a clinical vs. a healthy population etc.). Various analyses may be applied to resting state data, such as functional or effective connectivity analyses.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.tics.2013.09.016

https://doi.org/10.1016/j.neuroimage.2012.06.011

https://doi.org/10.1016/j.neuroimage.2012.01.044

https://doi.org/10.1016/j.jneumeth.2009.11.010

https://doi.org/10.3389/fnsys.2010.00019

Related terms: task period, spontaneous resting-state activity, resting-state functional connectivity

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Stimulus

Definition: A stimulus is an intentionally introduced event or object by the experimenter that is presented to the participant and is aimed at being detected, requiring a reaction, or influencing the participant in some way. It is typically designed to elicit a specific response or to observe the impact on the participant's behavior, perception, physiology or cognition.

Alternative definition:

Synonym:

References: https://link.springer.com/content/pdf/10.3758/BF03207787.pdf

Related terms:

Stimulus duration

Definition: The duration (measured in milliseconds, seconds, or minutes) that a stimulus is presented to the participant, from stimulus onset to stimulus offset.

Alternative definition: (if applicable)

Synonym:

References:

Related terms: Stimulus onset, Stimulus offset

Stimulus onset

Definition: Stimulus onset is the time-point when a specific stimulus first appears or is presented.

Alternative definition:

Synonym: onset

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1038/nn.2501

Related terms: Stimulus offset

Stimulus offset

Definition: Stimulus offset is the time-point when a specific stimulus is stopped, removed, or turned off.

Alternative definition: (if applicable)

Synonym: offset

References: https://doi.org/10.3389/fnhum.2022.821539

Related terms: Stimulus, Stimulus onset

Stimulus Onset Asynchrony

Definition: Stimulus onset asynchrony describes the time period between the onset of one stimulus (S1) and the onset of the next stimulus (S2). The two stimuli may vary to a large extent in terms of similarity (e.g., S1: sound; S2: word). The stimulus onset asynchrony can be manipulated experimentally to determine the effects on dependent measures such as reaction time or brain activity, or to account for systematic physiological factors that can affect the interpretation of results.

Alternative definition:

Synonym:

References: Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. Attention and Performance X: Control of Language Processes, 32, 531–556.

https://doi.org/10.1111/j.1467-9280.2006.01690.x

Related terms: Stimulus, Reaction Time, Priming, Inter-stimulus/trial interval, Jitter

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Stroop task

Definition: The Stroop task is a cognitive task in which a (physical) property of a stimulus can be congruent or incongruent with the stimulus' meaning or function. In one of its most common versions, the color in which a word is written may be the same as the meaning of the word (the word "blue" written in blue font) for the congruent condition and different from it ("blue" written in red font) in the incongruent condition. Participants' performance on incongruent stimuli is usually poorer (i.e., more often incorrect) and/or slower than in the congruent trials because of the interference that ensues between the meaning/function and the physical property of a stimulus. The task is named after John Ridley Stroop.

Alternative definition:

Synonym:

References: https://doi.org/10.1037/10870-002

https://doi.org/10.1037/h0054651

Related terms:

Task

Definition: A task is an experimental condition or manipulation set by an experimenter who instructs participants to respond in a particular way to a particular set of stimuli. For example, in a Stroop task, the participant is instructed to respond to the color of the letters (not the word meaning). Tasks can be very simple (e.g., watch the movie) or very complex (task switching studies) but they provide the primary way by which an experimenter can direct the cognitive processes of a participant and then analyze the neural systems engaged in those cognitive processes.

Alternative definition:

Synonym:

References:

Related terms: Block-design; Event-related design; Experimental Paradigm

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Task period

Definition: In an experiment, task period refers to the time interval during which the participant is engaged in a particular activity or experimental condition that is designed to evoke a hemodynamic response in the brain. The task period is often preceded and followed by a baseline or rest period, and task and rest periods are typically repeated several times throughout the experiment.

Alternative definition:

Synonym: task periods

References: https://doi.org/10.1109/ACCESS.2020.2993620

Related terms:

Trigger

Definition: A trigger is a timing marker of experimental events and is typically used to synchronize various signals in time. A trigger is represented by a certain value (e.g., numbers, letters), with different values indicating different events (e.g., start or end of a stimulus, trial, block, or condition).

Alternative definition:

Synonym: Stimulus marker, Event marker

References:

Related terms: Stimulus onset, Stimulus offset, Response onset, Block design, Event-related design, Lab Streaming Layer (LSL)

Within-participant design

Definition: Within-participant design is a type of study design where each participant is exposed to every experimental condition or treatment. One of the main benefits of a within-participant design is that it reduces the noise that can be attributed to inter-individual variation across participants.

Alternative definition:

Synonym: Within-group design, Within-subject design

References: https://doi.org/10.1073/pnas.1510343112

https://doi.org/10.1073/pnas.0806530105

Related terms: Between-participant design, Individual differences, Experimental design

3D-Digitizer

Definition: A three-dimensional (3D) digitizer measures the exact location of specific points on a real-world object and converts this information into a set of 3D points in a coordinate system. It is typically used to record the position of fNIRS optodes on the participant's head together with reference points or anatomical landmarks. Later this information can be used to obtain MNI coordinates of the optodes or channels by using spatial registration tools.In contrast to non-contacting 3D Scanners, which utilize technologies such as lasers, sound, or magnetism to scan an entire object or area, 3D digitizers are close-distance systems that use a stylus or articulated arm to mark points on an actual object based on an electromagnetic field.

Alternative definition:

Synonym: Digitizer

References: https://doi.org/10.1016/j.neuroimage.2005.05.019, https://doi.org/10.1109/EMBC.2013.6611270

https://peerj.com/articles/11804/

10.1002/oa.1156

Related terms: spatial registration, 3D Scanner

Accelerometer

Definition: Accelerometer is a device that measures the acceleration caused by movement and gravity, typically in one or more of the three planes of movement and/or three rotational axes. In fNIRS applications, accelerometers can be used to measure the amount, degree, and timing of head and/or body movements during measurement to regress out corresponding motion artifacts from brain hemodynamics.It can also be used to flag potential artifacts for further analysis and/or, in cases when movement is part of the protocol, to relate the type of movement to the measured signal.

Alternative definition:

Synonym: Motion Sensor

References: https://doi.org/10.1016/j.jneumeth.2015.02.006

https://doi.org/10.1117/1.3606576

https://doi.org/10.1016/j.neuroimage.2019.116472

https://doi.org/10.1016/j.neuroimage.2019.06.021

Related terms: motion, movement, motion artifact, movement artifact, gyroscope, Inertial Measurement Unit (IMU), sensor, wearable fNIRS, portable fNIRS, fDCS

Ambient Light

Definition: Ambient light is any light that does not originate from the emitters of the fNIRS device (e.g., sunlight, neon light). Depending on their nature, some ambient light sources may affect fNIRS measurements. For instance, they may introduce additional noise into the fNIRS signal or fully saturate the detectors.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.ijleo.2020.165116

https://doi.org/10.4172/2167-1222.1000258

https://doi.org/10.1016/j.ijleo.2020.165116

Related terms: Optode Cover

Average Optical Power

Definition: Average optical power is the mean power of an optical signal (e.g. continuous light or repeated light pulses) within a specific period of time.

Alternative definition:

Synonym:

References:

Related terms:

Broadband NIRS

Definition: Broadband NIRS (bNIRS) is an optical imaging technique that measures in-vivo changes in tissue hemodynamics (oxyhemoglobin and deoxyhemoglobin) and, often, other biomarkers such as metabolism (e.g., redox state of cytochrome-c-oxidase or (oxCCO)). Tissue light attenuation measurements are performed at a larger number of wavelengths than typical 2-4 wavelength NIRS instruments, e.g., spanning 600 to 1000 nm at 1 nm wavelength resolution, to reduce crosstalk effects and noise.In contrast to fNIRS systems, bNIRS use broadband light sources, for example, a tungsten halogen light source emitting light between 200 - 2500 nm and a wavelength-dependent detector (e.g., a spectrophotometer). Optical filters may be placed in the source or detector optical path to narrow the spectrum to the region of interest.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.JBO.21.9.091307

https://doi.org/10.3390/metabo12030260

https://doi.org/10.1038/s41598-021-83420-9

https://doi.org/10.1364/BOE.3.000064

https://doi.org/10.1117/12.700894

Related terms: multi-wavelength fNIRS

Calibration

Definition: The set of operations which establish, under the conditions of the experiment to be run, the relationship between values indicated by a measuring instrument or measuring system, or values, represented by a material measure, and the corresponding known value of a measurand or its derivative. The result of a calibration permits the estimation of errors of indication of the measuring instrument, or the assignment of values to marks on arbitrary scales. The result of a calibration is sometimes expressed as a calibration factor, or as a series of calibration factors in the form of a calibration curve.

Alternative definition:

Synonym:

References: G. van der Horn and J. Huijsing, Integrated Smart Sensors: Design and Calibration. The Springer International Series in Engineering and Computer Science. Springer US, 1997. https://link.springer.com/book/10.1007/978-1-4757-2890-3

Related terms:

Cap

Definition: Cap is a wearable garment that is put on a participant's head to stabilize the positions of the optodes (i.e., hold the light sources and detectors in place) and ensure continuous contact of the optodes with the scalp. It affects (long-term) wearing comfort and can be therefore made of various materials, such as stretchable fabrics, rubber, silicone, or foam, and is often designed to fit a specific head size and shape.It typically has built-in holders or holes to insert the probes or modules. A cap also plays an important role in isolating detectors from ambient light.

Alternative definition:

Synonym:

References: https://doi.org/10.1364/ao.54.000576

Related terms: headgear

Dark Noise

Definition: Dark noise refers to the signal detected by a sensor when no input is present. Ideally, a perfect optical sensor should have a noiseless zero output signal in the absence of light, indicating no background signal or noise. In practice, inherent electronic noise, dark current noise, thermal noise combine to produce a non-zero output signal with noise despite a lack of input light. High dark noise levels and/or a large relative variation of dark noise levels can reduce the quality of measurement data.

Alternative definition:

Synonym:

References: Radiometric Calibration: Theory and Methods, Chapter Dark-Noise Analysis, Clair Wyatt

https://doi.org/10.1117/12.790659

Related terms: correlated noise, after pulsing, dark current noise, dark current, thermal noise, electronic noise, ambient light, background signal

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Detector

Definition: Detector is an optoelectronic element that receives light and converts it into electrical signals. In fNIRS, a detector typically refers to a device, such as an avalanche photodiode or a photomultiplier tube that detects the near-infrared light that has passed through the measured tissue.

Alternative definition:

Synonym: Receiver, Sensor

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov. https://doi.org/10.1117/12.2037559, https://www.rp-photonics.com/photodetectors.html,

https://doi.org/10.3390/app10186522,

Related terms: Sensor, Source, Photomultiplier Tube, Avalanche Photodiode, Photodiode, Photodetector, Silicon Photomultiplier

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Detector Optode

Definition: Detector (or detection) optode is a common term which often identifies a part of an fNIRS system that is in contact with the surface of the tissue being measured. A detector optode either directly contains the photodetector (see definition of "detector") or can hold the distal end of the detector fibers, and may also include a light guide, a lens, an optical filter and a housing.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov. https://doi.org/10.1117/12.2037559, https://www.rp-photonics.com/photodetectors.html,

https://doi.org/10.3390/app10186522,

Related terms: Optode, Detector, Motion Sensor, Source, Photomultiplier Tube, Avalanche Photodiode, Photodiode, Photodetector, Silicon Photomultiplier

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Detector Sensitivity

Definition: Detector sensitivity refers to the ability of the detector to convert incoming light/photons into an electrical signal. It is defined as the ratio of the change in the output quantity of the detector against the change in the input quantity of the detector (also known as responsivity). It can be formulated as the observed change in the output current of the detector for a change in the power of the incident light in fNIRS devices (unit: Ampere/Watt or Ampere/Lumen). Detector sensitivity can be affected by several factors, including the detector material, the size and shape of the detector, the quality of the optics, and the electronics used to amplify the detector signal.

Alternative definition:

Synonym:

References: https://doi.org/10.1201/9781315217109

Related terms: Detector, Detectivity, Responsivity, Noise equivalent power

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Diffuse optical tomography

Definition: Diffuse optical tomography (DOT) refers to the use of a tomographic algorithm to reconstruct, at least (but not limited to) oxygenated and deoxygenated hemoglobin concentrations volumetrically from multiple spatially distinct measurements. This 3D reconstruction can improve quantification and localization of cortical hemodynamics.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.6.3.035007

https://doi.org/10.1364/AO.45.008142

Related terms: high-density DOT, diffuse optical imaging (DOI), fNIRS, NIRS

Dual slopes

Definition: Dual slope approach requires at least two sources and two detectors organized in specially structured arrays and either a continuous-wave (CW) or frequency domain (FD) system. The approach gives increased sensitivity to deeper tissue as well as more robustness to experimental errors and variability in opto-mechanical coupling. The spatial gradient of DC amplitude, AC amplitude, or phase vs source-detector distance is referred to as the slope.

Alternative definition:

Synonym:

References: https://doi.org/10.1364/JOSAA.36.001743

Related terms:

Fiber optic

Definition: Fiber optic is a filament of a dielectric material that has transparency to a portion of the optical spectrum and structure so that light is propagated through the fiber. It consists of a central core surrounded by a cladding. In a typical step-index fiber, the core has an index of refraction n_{1} that is slightly higher than that of its surrounding cladding n_{2}. In a ray-optics model, illuminating the end of the fiber starts rays along many possible paths in the core and cladding. A ray whose path meets the core-clad boundary at a small enough angle is reflected back into the core, and thereby, is confined to the core by a series of total internal reflections and such a ray may thus propagate for long distances (>km) in the fiber core. Similar principles apply to graded-index fiber optics for which the transition between n_1 and n_2 is gradual.

Alternative definition:

Synonym: optical fiber, glass fiber, optical guide

References: Optical Materials: Volume 1. Optical Materials. Taylor & Francis, 1990

https://doi.org/10.1201/9781003210139

Related terms:

Frequency domain multidistance NIRS

Definition: By capturing the change in intensity and phase at multiple source detector separations/distances, the frequency-domain (FD) multidistance NIRS technique can estimate absolute values of absorption and scattering of the medium, and subsequently chromophore concentrations. This may involve one or more modulation frequencies. The key here is that these measurements are taken at multiple source detector separations as opposed to one. Ideally, this allows one to obtain the optical properties of the medium under investigation without performing a calibration measurement on a tissue-like medium. Additionally, this allows a simpler processing method requiring linear regression only instead of non-linear optimization to get absorption and scattering of the medium. However, most practical multi-distance frequency-domain multidistance NIRS systems do utilize a phantom calibration of the coupling coefficients between the sources/detectors and media.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/12.183988

https://dx.doi.org/10.1088/0031-9155/46/1/304

https://doi.org/10.1364/BOE.2.000552

Related terms: frequency domain, source detector separations, time domain, continuous wavelength fNIRS

Frequency multiplexing

Definition: Distinguishing different channels by modulating the light source at non-overlapping frequencies. In fNIRS devices, each light emitter can be codified with a specific frequency modulation through frequency multiplexing, which allows simultaneous detection of all sources at any given detector. The demultiplexing would then be employed to measure the amount of signal detected coming from each source.

Alternative definition:

Synonym: NaN

References: DOI: 10.1117/1.nph.8.1.012101

Related terms: Time multiplexing

Full width at half maximum of spectral power distribution

Definition: Difference of the wavelength between the two points whose corresponding power values are equal and 3 dB lower than

the values at each peak wavelength.

Alternative definition:

Synonym:

References: IEC 80601-2-71:2015, 201.3.204

Related terms: peak wavelength

Gyroscope

Definition: A gyroscope is a device that measures or maintains orientation and angular velocity (in rad/s). It consists of a spinning rotor that detects changes in angular velocity when the frame it is mounted on rotates. Gyroscopes can be used independently or integrated into inertial measurement units (IMUs). In fNIRS, gyroscopes are often used in combination with an accelerometer mounted at the optode level to track head motion (i.e., position and orientation) during data acquisition.

Alternative definition:

Synonym:

References: https://doi.org/10.3390/s17102284

Related terms: Accelerometer, Inertial Measurement Unit (IMU), Motion Artifacts

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Headgear

Definition: Equipment and materials that hold the sources and detectors in a specific source-detector arrangement with a good scalp coupling at the desired location on the head. Headgear may include optode grids that maintain a fixed source-detector spacing as well as headbands or caps to place the optodes on the head.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neubiorev.2009.07.008

https://doi.org/10.1016/j.dcn.2018.01.009

http://dx.doi.org/10.1016/j.dcn.2016.11.005

http://dx.doi.org/10.3389/fpsyg.2011.00222

Related terms: Cap

High Density Source-detector Array

Definition: Arrangement of sources and detectors in an interlaced lattice with the first nearest neighbor distance of up to 15 mm in adults for most implementations. It would be different in an infant head. The term “high density” allows it to be differentiated from the “traditional” sparse optode placement with several cm (~3) between optodes.

Alternative definition:

Synonym:

References: https://doi.org/10.1063/1.5086809

https://doi.org/10.1109/OJEMB.2023.3248492

https://doi.org/10.1117/1.NPh.10.2.025007

https://fnirs.org/2022/01/01/sfnirs2022_34/

Related terms: High Density Diffuse Optical Tomography (HD-DOT), Ultra-high density (UHD)

High-Density Diffuse Optical Tomography

Definition: High-Density Diffuse Optical Tomography (HD-DOT) imaging systems use dense, as in "High Density Source-detector Array", often regularly spaced arrays of near-infrared sources and detectors to obtain overlapping measurements of the underlying hemodynamic activity. Compared to conventional multichannel fNIRS systems, the measurements obtained from source-detector pairs across various increments of neighboring distances facilitate higher spatial resolution and depth profiling. This allows a three-dimensional tomographic spatial reconstruction of cortical activity patterns comparable to those obtained using fMRI.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.2.2.025005

https://doi.org/10.1016/j.neuroimage.2009.07.033

https://doi.org/10.1016/j.neuroimage.2012.01.124

https://doi.org/10.1016/j.neuroimage.2015.05.058

https://doi.org/10.1080/23273798.2017.1290810

https://doi.org/10.7554/eLife.75323

https://doi.org/10.1063/1.5086809

https://doi.org/10.1117/1.3368999

Related terms: Diffuse Optical Tomography (DOT), Ultra-high density (UHD), High Density (Source-detector Array)

Imager

Definition: In the field of neuroimaging, an imager is a device records and visualizes (live) the spatial distribution of brain activity status (hemodynamic changes). Visualization typically occurs through acquisition software, presenting data in the form of diagrams, 3D models, or topographic maps to monitor the brain activity. They can be categorized as either mobile/wearable imagers or stationary/laboratory devices, depending on their portability.

Alternative definition:

Synonym: imager system, imaging system, imaging device, fNIRS imager

References: https://doi.org/10.1109/NEBC.2003.1215988

https://doi.org/10.1063/1.4704456

https://doi.org/10.1117/12.341439

https://doi.org/10.1007/978-3-319-91287-5_22

https://doi.org/10.1016/j.neuroimage.2012.03.049

Related terms: Mobile fNIRS device

Inertial measurement Unit (IMU)

Definition: An Inertial Measurement Unit (IMU) is a device that measures acceleration, angular velocity, and sometimes the body's

orientation, using a combination of accelerometers, gyroscopes, and/or magnetometers. It is often used for motion tracking in robotics, virtual reality, and other applications. In fNIRS research, IMU can be attached to the subject's head to track head motion during an fNIRS experiment, and this information can be used to remove the effects of head motion on the fNIRS data.

Alternative definition:

Synonym:

References: https://doi.org/10.1109/TNSRE.2020.2987888

https://doi.org/10.1186/s12938-018-0554-9

Related terms: Motion Correction, Accelerometer, Gyroscope, Magnetometer

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Instrument response function

Definition: A gauge of how the components of a time-domain (TD) fNIRS system affect the experimental data. The IRF is measured by recording a histogram of photon arrival times using the TD fNIRS system and optodes, with a carefully-designed mechanism replacing the tissue in the measurement optical light path which provides both optical attenuation and sufficient scattering, without broadening the laser pulse itself. The IRF is influenced by the laser pulse shape, the temporal response of the detector and electronics, and pulse broadening due to temporal dispersion in the optics.

Alternative definition: The IRF characterizes the time resolution of a time-domain (TD) fNIRS system. The IRF is determined by inserting a reference sample between source and detection components of the instrument which replaces the tissue and introduces negligible additional temporal dispersion. The IRF depends on the laser pulse shape, the temporal response of the detector and electronics, and pulse broadening due to temporal dispersion in the optics, and is represented as a convolution of these individual effects.

Synonym:

References: http://dx.doi.org/10.1016/j.neuroimage.2013.05.106

Related terms: TD fNIRS

Light-emitting diode

Definition: Light-emitting diode is a p-n junction, a semiconductor-based optoelectronic device, driven by a current I into forward bias. Electrons and holes recombine close to the junction between the p- and n-materials and give out radiation with a frequency determined by the photon energy which in turn is determined by the material’s impurities or band gap. Some fraction of the forward current I is then turned into useful light L (power) formed from photons with a mean energy hf_{m}. The quantum efficiency is $\eta = (eL/hf_{m}I)$. The more efficient light emitting diodes have a well-defined recombination region (volume Φ).

Alternative definition: An LED is a semiconductor device in which light is generated when an electric current is passed through it. The generated light has a wider spectral width and lower output power compared to a laser. However, LEDs have the advantage of being fairly inexpensive and portable.

Synonym:

References: J.E. Carroll. Rate Equations in Semiconductor Electronics. Cambridge University Press, 1990.

Related terms: emitter, source, laser, transmitter

Magnetometer

Definition: A magnetometer is a device that measures a surrounding magnetic field (e.g., the Earth’s magnetic field). Magnetometers are often included in inertial measurement units where they are used as the heading reference and to define the orientation of an object with respect to the Earth. Pairing a magnetometer with an accelerometer and gyroscope can improve the identification and removal of motion artifacts. Magnetic field strength is measured in micro Tesla (μT).

Alternative definition:

Synonym:

References: https://doi.org/10.1186/s12938-018-0554-9

Related terms: inertial measurement unit, accelerometer, gyroscope

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Measurement Channel

Definition: A channel in fNIRS is typically the combination of a source and a detector that together produce a single stream of measurement data from a circumscribed portion of underlying brain (or other) tissue. A channel's position is marked mid-way between its source and detector pair in a 3D space, which also indicates the surface projection of the underlying brain area where emitted photons have the highest probability of interacting with brain tissue.

Alternative definition:

Synonym: Channel, Source-detector pair

References: https://doi.org/10.1186/s12938-018-0554-9

Related terms: Short-separation channel

Mobile fNIRS device

Definition: Mobile devices are lightweight, portable and wearable. Due to their compact and robust design, mobile fNIRS devices can be used outside the laboratory/controlled environment and in everyday life situations, enabling freely moving participants in unrestrained settings.

Alternative definition:

Synonym: Portable fNIRS, Wearable fNIRS, Mobile Device

References: https://doi.org/10.1111/nyas.13948, https://doi.org/10.1364/BRAIN.2020.BM3C.2

Related terms: Naturalistic environment, Unrestrained settings, Movement

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Modulation Frequency

Definition: Modulation frequency is the frequency (f) at which the amplitude of light is changed or modulated, in a source in frequency domain hardware.The light detected in frequency domain hardware has three components: the DC intensity, which is analogous to continuous wave measurement, the AC intensity (I) , which is the intensity of light oscillating at the given modulation frequency, and the phase (ϕ), which represents the phase difference of the emitted and detected modulated light. The phase of the detected light therefore provides information regarding how much it has been delayed (on average) as a result of photon interactions with a medium, i.e scattering. The phase is directly related to the time delay of light, τ , such that ϕ is in the order of $\omega\tau$, where $\omega=2\pi f$ and ω is the angular modulation frequency. For a good signal to noise ratio, it is required that $\omega\tau \approx 1$(radians). If $\omega\tau$ is $\ll 1$, there would not be a measurable phase change. If $\omega\tau$ is $\gg 1$, then the AC amplitude decreases and could be below the level of noise. In the context of imaging biological tissue, time delays are on the order of nanoseconds (for source-detector separations of 2-3 centimeters), which yields optimum modulation frequencies in the order of 100 MHz.

Alternative definition:

Synonym: Angular modulation frequency

References: https://doi.org/10.1364/BOE.467614

https://doi.org/10.1117/3.2219603

https://doi.org/10.1017/cbo9781139029797

Related terms: Frequency domain, Phase

Multi Modulation Frequency fNIRS (mFD-fNIRS)

Definition: Frequency Domain measurements are typically taken at a single modulation frequency. The three measured signals from these measurements are the direct current amplitude, alternating current amplitude, and phase. These signals have a modulation frequency dependence. Multi Modulation Frequency fNIRS (mFD-fNIRS) combines multiple measurements of FD-fNIRS at different modulation frequencies, either simultaneously or by repeated measurements, each at a discrete modulation frequency. The measurements at discrete modulation frequencies are then used simultaneously for spectroscopic or tomographic reconstruction of optical properties. In current literature, the frequencies typically range from tens of MHz to 1000 MHz and have been shown to increase localization and better image resolution compared to single modulation frequency FD-fNIRS.

Alternative definition:

Synonym:

References: https://doi.org/10.1364/BOE.435913

https://doi.org/10.1364/BOE.467614

https://doi.org/10.1117/1.NPh.8.4.045002

Related terms: Frequency Domain, Modulation Frequency

Noise Equivalent Power

Definition: Noise Equivalent Power (NEP) quantifies the sensitivity of a detector (also often used for the instrument to define the sensitivity of the entire system). It is the minimum input power required to produce a usable output signal in the presence of noise, or in other words, a measure of the weakest optical signal that can be detected. Therefore, it is desirable to have a NEP as low as possible since a low NEP value corresponds to a lower noise floor and, consequently, a more sensitive detector. A low NEP is beneficial even at higher input intensities since it will lead to lower noise characteristics in the output signal.Technically, NEP is the input power that produces a signal-to-noise ratio (SNR) of one in a 1 Hertz (Hz) bandwidth. For photodetectors it is given in Watts per square root of Hertz (W/√Hz). However, it is also not uncommon to list a system's sensitivity in terms of its total individual bandwidth in Watts only. Typical dimensions in the field of fNIRS are in the magnitude of pW To calculate Noise Equivalent Power, it is necessary to know the spectral sensitivity of the photodetector, dark noise performance, measurement bandwidth, and the current-to-voltage conversion factor.

Alternative definition: Noise equivalent power is a metric used to evaluate the sensitivity of a detector, which is the minimum input power required to produce a usable output signal in the presence of noise. The lower the NEP value, the more sensitive the detector is, since a low NEP corresponds to a lower noise floor. NEP is calculated as the input power that produces a signal-to-noise ratio (SNR) of one in a 1 Hertz (Hz) bandwidth, typically measured in Watts per square root of Hertz (W/√Hz). In the field of fNIRS, NEP values are typically in the magnitude of picoWatts (pW).

Synonym:

References: 10.3390/s20102831, 10.3390/s21186106, 10.1016/j.neuroimage.2022.119216, Corpus ID: 7011179, https://www.thorlabs.com/images/TabImages/Noise_Equivalent_Power_White_Paper.pdf

Related terms: detector, performance, sensitivity

Optical Loss

Definition: Optical loss refers to the reduction in light intensity or power as it propagates through a medium (e.g. tissue or phantom). This loss occurs due to various factors such as absorption, scattering, and reflection of light. Optical loss can be quantified as the ratio between the input optical power (light emitted by the sources) and the output optical power (light received by the detectors after traversing the medium). This ratio, often expressed in decibels (dB), provides a measure of how much the emitted light signal has attenuated or weakened by the time it reaches the detectors.

Alternative definition:

Synonym:

References: 10.3390/s20102831, 10.3390/s21186106, 10.1016/j.neuroimage.2022.119216, Corpus ID: 7011179, https://www.thorlabs.com/images/TabImages/Noise_Equivalent_Power_White_Paper.pdf

Related terms: functional NIRS phantom

Optode cover

Definition: An optode cover is a protective layer of material placed over an optode to prevent ambient light from being recorded by the detectors.

Alternative definition:

Synonym: light shield

References: https://doi.org/10.1289%2FEHP2049

Related terms:

Peak Wavelength

Definition: Wavelength where the power is the largest in the spectral power distribution for each of the distinct nominal wavelengths in the light radiated from the emitter optode.

Alternative definition:

Synonym:

References: IEC 80601-2-71:2015, 201.3.214

Related terms: Full width at half maximum of spectral power distribution

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Phantom

Definition: Phantoms, whether material or digital (simulations), serve as models to validate the quantitative results of imaging systems. They are specifically designed to mimic certain in vivo characteristics and the data collected using phantoms can be used as reference values for in vivo measurements.In the field of fNIRS, researchers use various types of material phantoms: (1) Solid phantoms which are made of a solid material like epoxy resin or polyoxymethylene containing scattering constituents, such as titanium oxide (TiO2), and absorbing constituents, such as nigrosin. Solid phantoms are commonly static and cannot model dynamic changes within the brain unless an inhomogeneity is being mechanically moved (or thermoelectrically activated) within the phantom. (2) Semi-solid phantoms which are made of a gel-like material containing scattering and absorbing particles and help test the effects of tissue movement and deformation on fNIRS signals. (3) Liquid phantoms that consist of a solvent (e.g., water), a scattering agent (e.g., fat emulsion, latex spheres), and an absorber (e.g., ink, hemoglobin). Glycerol may be added to change the viscosity, simulating a change in blood flow for DCS and similar techniques. They can model dynamic changes, however, these phantoms are typically not stable over long periods (weeks) and layered models (e.g., to simulate the brain and superficial layers) are challenging. (4) Multi-layer phantoms are made of multiple layers of different materials with different optical properties to simulate the layered structure of human tissue, e.g., solid compartments modeling the superficial layers of the head and a liquid section mimicking the brain layer. Digital (simulation) phantoms refer to different means of simulating (often with added noise) the effects of layers, heterogeneities, optical properties, boundaries and others on the detected signals. They can be used to test different algorithms of signal analysis, to design new hardware and to aid the interpretation of in vivo data.

Alternative definition:

Synonym:

References: https://doi.org/10.1002/nbm.4421

https://doi.org/10.1186/s40658-020-00320-z;

https://doi.org/10.1364/BOE.9.002068;

https://doi.org/10.1088/0031-9155/40/5/016;

https://doi.org/10.1109/TIM.2020.2990261;

https://doi.org/10.1117/1.JBO.20.12.121304

Related terms:

Photomultiplier tube

Definition: Photomultiplier tube (PMT) is a photodetection device equipped with a photocathode and electron multiplier utilized for its high gain and low light sensing capabilities. When a photon strikes the photocathode, a single photoelectron is emitted from this site. The photoelectron is then accelerated using electric fields to a structure known as a dynode. After striking the dynode, additional electrons are released which are then sent to another dynode. This process will continue for as many dynodes as contained in the PMT. The resulting photoelectron gain is ~1x106 to 1x107. In analog mode, the output of the device is a current that can be measured directly from the device. Additionally, a PMT can operate in photon counting mode, which, when combined with a pulse height discriminator and timing and counting electronics, may be utilized for TD-fNIRS.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/B0-12-369397-7/00529-X,

https://hamamatsu.magnet.fsu.edu/articles/photomultipliers.html

Related terms: Avalanche Photodiode, Silicon Photomultiplier, Detector, Sensor

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Power

Definition: Radiant power refers to the amount of energy per unit time emitted by electromagnetic radiation, measured in watts (W) or decibels relative to a milliwatt (dBm)

Alternative definition:

Synonym:

References: https://doi.org/10.1089/pho.2009.2503

Related terms: source, detector

Response Time

Definition: Time required for the step response of the equipment to move from its specified percentage of the final steady-state value to the other specified percentage. Response time is conventionally denoted by the rise time or fall time that represents the interval between the times corresponding to 10 % and 90 % of the step response amplitude during the transition.

Alternative definition:

Synonym: probeset

References: IEC 80601-2-71:2015, 201.3.215

Related terms:

Sensor

Definition: In the context of fNIRS, a sensor typically refers to a device, such as an avalanche photodiode or photomultiplier tube,

that detects the near-infrared light that has passed through or reflected from the measured tissue. Some fNIRS systems additionally incorporate other physiological sensors, such as electroencephalography (EEG) or electrocardiography (ECG), and motion sensors like accelerometers or gyroscopes. These sensors capture other physiological signals that may be relevant to the study, providing complementary information to fNIRS measurements. By offering a more comprehensive understanding of brain activity and associated physiological responses, these sensors can contribute to improving accuracy and interpretation of the results.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.3390/photonics6030087

Related terms: Optode, Detector, Motion Sensor

Short-separation channel

Definition: A short separation channel is generated by placing a source and a detector at a short distance, in case of the adult brain, this is typically ~ 1 cm or less, in contrast to regular long-separation channels with ~3 cm source-detector distances. At such distances, channels are mostly sensitive to systemic activity resulting from extra-cerebral tissues (i.e., scalp and skull). The signal from these channels can be used to regress out extra-cerebral contaminations from the long-separation fNIRS signal in order to isolate the cortical functional response.

Alternative definition:

Synonym: short-distance channel, short channel

References: e.g. https://doi.org/10.1016/j.neuroimage.2013.04.070

https://doi.org/10.1117/1.NPh.2.2.025005

https://doi.org/10.1117%2F1.NPh.3.3.031405

Related terms: Extra-cerebral signal, Source-detector separation, Measurement Channel

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Silicon Photodiode

Definition: A silicon photodiode (SiPD) is a silicon solid-state device that takes photons in and puts electrons out, usually at the rate of about 5 electrons out for every 10 photons. It produces current when photons impinge upon it; a silicon photodiode does not require an external power source in order to operate. SiPDs are commonly used as detectors in fNIRS systems because they are sensitive to light in the near-infrared spectrum. They are compact, fast, and have low noise, making them well-suited for use in wearable fNIRS systems besides laboratory systems.

Alternative definition:

Synonym:

References: https://doi.org/10.1364/AO.39.006466

Related terms: Detector, Sensor

Silicon Photomultiplier

Definition: The silicon photomultiplier (SiPM) is a type of sensor/detector with compactness, wide dynamic range, fast timing, and high gain factors. SiPMs are solid-state photodetectors made of an array of hundreds or thousands of integrated single-photon avalanche diodes (SPADs), called microcells or pixels whose outputs are merged into one, and therefore result in high sensitivity, wide dynamic range, and gain factors of 105 to 106, while allowing small construction sizes to even 1.1 x 1.1 mm2 frame sizes. Upon detecting a photon, the SPAD generates a large electrical output signal due to internal avalanche multiplication. The SiPM

allows one to detect and count photons with high resolution and single photon sensitivity. The internal avalanche amplification is also fast enough to obtain excellent timing information on the arrival time of the detected photons within several tens of picoseconds. However, the supply voltage depends on the APD technology used. It typically varies between 20 V and 100 V, thus being from 15 to 75 times lower than the voltage required for a photomultiplier tube's (PMT) operation but also 5 to 20 times higher than for a SiPD. These high voltages require additional safety measures for applications on the human head. Furthermore, like APDs, SiPMs have a high temperature sensitivity and increased noise components. However, SiPMS have a smaller dynamic range and saturation occurs at lower light levels when compared to APDs

Alternative definition:

Synonym: solid-state photomultiplier (SSPM), or multi-pixel photon counter (MPPC)

References: https://doi.org/10.1088/1361-6560/ab7b2d

https://doi.org/10.1142/9789812776464_0101

Related terms: avalanche photodiode, APD, silicone photodiode, SiPD, detector, sensor, single photon avalanche diodes, SPAD, PMT, photomultiplier tube

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Smart Textiles

Definition: Smart textiles (ST) are fabrics-based products that can sense (Passive ST), react (Active ST), and even adapt (Ultra ST) to their environment, whereby stimuli can have an electrical, photonic, thermal, chemical, magnetic, etc. origin. For this, they are fitted with electronic components to process information. The decision can occur locally in embedded electronic devices or remotely via connected external systems.

Alternative definition:

Synonym: Smart Clothing, Smart Garments, Smart Fabrics

References: https://doi.org/10.1007/978-3-319-50124-6_1

https://shop.elsevier.com/books/smart-textiles-and-their-applications/koncar/978-0-08-100574-3

https://doi.org/10.3390/s140711957

Related terms: headgear, headband, caps, patches, armband, shirt, detectors, sources

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Source

Definition: Source is an optoelectronic element that delivers light (e.g. a laser or an LED). In fNIRS, it refers to a source of near-infrared light that is used to illuminate a tissue being interrogated. Sources can either require optic fibers to carry the light to source optodes placed on the scalp or can be integrated into optodes, wearable probes or modules placed directly on the scalp.

Alternative definition:

Synonym: emitter

References: https://doi.org/10.1146/annurev-psych-010213-115108

https://doi.org/10.1016/S0006-3223(02)01550-0

https://doi.org/10.3390/s21186106

https://www.intechopen.com/chapters/28786

Related terms: detector, source-detector pair, channel, probe, diode

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Source-detector pair

Definition: A set of two optodes (one light source and one detector) which is considered as a single measurement unit (i.e., measurement channel). Although in theory any source can be paired with any detector, most systems/researchers set up a region of interest- and a distance-criteria (how far away from each other are the two optodes located, i.e., source-detector separation) to define source-detector pairs that interrogate the brain. A single optode (either source or detector) can be part of multiple source-detector pairs.

Alternative definition:

Synonym: SD pair, measurement channel, S-D combination

References: https://doi.org/10.1118/1.1354627

https://doi.org/10.1038/s41598-018-21716-z

Related terms: source, detector, array, optode, montage, High Density (Source-detector Array), measurement channel

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Source Optode

Definition: Source or injection optode is a common term which often identifies a part of an fNIRS system that is in contact with the surface of the tissue being measured. A source optode either directly contains the light sources (e.g. for an LED-based system), or can hold the distal end of source fibers (e.g. for a laser-based system) emitting light at two or more wavelengths. This component may also contain a light guide, a lens, and a housing.

Alternative definition:

Synonym: Emitter Optode

References:

Related terms: Source, Detector, emitter, optode

Time multiplexing

Definition: Time multiplexing is a method of transmitting and receiving two or more independent signals over a common channel path by means of synchronized switches at each end of the transmission line. This way each signal appears on the line only a fraction of time in an alternating pattern. In fNIRS this technique of switching on and off different light sources at fixed intervals avoids the superposition of two sources being detected by a single detector simultaneously. This strategy is commonly employed in fNIRS devices to enable the detector to identify from which emitter the light came from. The temporal resolution of a device is inversely proportional to the number of time multiplexing steps and step width (i.e., the more steps there are, the slower the frequency of acquisition).

Alternative definition:

Synonym: Time division multiplexing

References: DOI: 10.1117/1.nph.8.1.012101; DOI: 10.1201/b17289 (section 7.3.1)

Related terms: Frequency multiplexing

Transmitter

Definition: In wearable/portable fNIRS systems, a transmitter refers to the communication unit worn by the subject. It may include sensors that record fNIRS data and other physiological data such as heart rate or motion. The recorded data can then be transferred wirelessly to a receiver unit using a variety of communication protocols, such as Bluetooth or Wi-Fi.

Alternative definition:

Synonym:

References: https://doi.org/10.1109/EMBC.2013.6609962

https://doi.org/10.3390/brainsci10020085

https://doi.org/10.1002/cta.3047

https://publications.polymtl.ca/1346/1/2014_EhsanKamrani.pdf

Related terms: Frequency multiplexing

Vertical Cavity Surface Emitting Laser

Definition: A Vertical Cavity Surface Emitting Laser (VCSEL) is a light-emitting, laser-based component that provides high wavelength stability with a very stable, short cavity. VCSEL of 3 or 4" wafers have less than a 2 nm standard deviation for cavity wavelength. A VCSEL operates in a single longitudinal mode, which avoids signal distortions due to mode beatings. It has low power consumption, and the circular output beam allows simpler optics than side-emitting lasers. Its temperature sensitivity of wavelengths is ~5 times less sensitive to temperature variations than edge emitters. Over a 20°C change in temperature causes the emission wavelength to vary less than 1,4 nm (edge emitters = ~7 nm).A VCSEL allows highly compact designs; it enables the packaging of multi-wavelength source chips with reduced placing shifts. However, as VCSEL's typical use field is in data transfer and heating systems, multi-wavelength emitters between 600 and 900 nm are not widely available to the public.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/12.2209320

https://doi.org/10.1117/12.2077209

https://doi.org/10.1117/12.2210909

https://doi.org/10.1117/1.3462996

Related terms: source, multi-wavelength, emitter, laser

Fast Fourier Transform

Definition: The fast Fourier transform (FFT) is a family of algorithms that computes a sequence's Fourier transform (FT) by decomposing a series of values into components with distinct frequencies. The distinctive characteristic of this family of algorithms is their computational efficiency; they reduce the number of computations for N points from N^2 to $NlogN$.

Alternative definition: Fast Fourier Transforms (FFT) is a family of efficient algorithms that computes the Fourier Transform (FT) of a sequence of data points. The discrete FT transforms a time-domain signal into its frequency-domain representation, which can be used to analyze and manipulate the signal. (Note, the use of terms time and frequency here are not intended in their physical meaning. Fourier transform can be applied to mathematical sets with no physical semantics.)

Synonym:

References:

https://doi.org/10.1109/MSPEC.1967.5217220

Related terms: Fourier transform, Discrete Fourier transform

Filter order

Definition: In signal processing, filter order refers to the number of poles (or zeros) in the transfer function of a filter. Poles and zeros are locations in the complex plane where the transfer function becomes infinite or zero, respectively. The order of a filter is equal to the number of poles or zeros, whichever is greater.The filter order is an important parameter because it determines the steepness of the filter's cutoff slope and its overall performance. Generally speaking, higher-order filters have steeper cutoff slopes,

which means they can more effectively attenuate unwanted frequencies while passing desired frequencies. However, higher-order filters also require more computational resources and can introduce more phase distortion, so there is often a trade-off between filter performance and complexity. The filter order can be mathematically represented as the highest power of the variable in the transfer function of the filter. For example, a first-order low-pass filter has a transfer function of the form: $H(s) = \frac{1}{s + \alpha}$ where s is the complex frequency variable and α is a constant. The filter order in this case is 1, since the highest power of s in the denominator is 1. Similarly, a second-order high-pass filter has a transfer function of the form: $H(s) = \frac{s^2}{s^2 + \beta s + \gamma}$ where β and γ are constants. The filter order in this case is 2, since the highest power of s in the denominator is 2. In general, the filter order can be determined by counting the number of poles (or zeros) in the transfer function, or by finding the highest power of the variable in the transfer function.

Alternative definition: The order of the filter refers to the maximum delay in samples used in generating each output sample. The higher the order the steeper the slope between passband and stopband.

Synonym:

References:

http://www.w3k.org/

ISBN 10: 0974560715

https://doi.org/10.1504/IJWMC.2018.089991

Related terms: Filter, FIR FIlter, IIR Filter, Preprocessing

FIR filter

Definition: An FIR (finite impulse response) filter is a type of digital filter that is commonly used to process signals in a wide range of applications, including audio processing, image processing, and biomedical signal processing. An FIR filter is characterized by a finite impulse response, which means that the output of the filter is a weighted sum of a finite number of past and present input samples. The impulse response of an FIR filter is typically a finite sequence of coefficients used to compute the output of the filter. The input signal is convolved with the impulse response to produce the output signal.In fNIRS, FIR is used to process and analyze the measured optical density data. FIR filters are often used in fNIRS analysis because they have several desirable properties. One of the main advantages of FIR filters is that they have a linear phase response, which means they do not introduce any phase distortion in the filtered signal. This is important in fNIRS analysis because changes in hemoglobin concentration can be affected by changes in the optical path length, which can introduce phase shifts in the measured signals. The mathematical representation of an FIR filter can be expressed as: $y[n] = b[0] \times [n] + b[1] \times [n-1] + b[2] \times [n-2] + \ldots + b[M] \times [n-M]$ where: $y[n]$ is the output signal at time n $x[n]$ is the input signal at time n $b[0], b[1], \ldots, b[M]$ are the filter coefficients M is the filter order The coefficients $b[0], b[1], \ldots, b[M]$ are typically determined by windowing, frequency sampling, and least squares techniques.

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fnins.2019.00737

https://doi.org/10.3389/fnhum.2018.00505

Related terms:

Fourier Transform

Definition: The Fourier transform (FT) decomposes data into its spectral (frequency) components. Originally developed by Jean-Baptiste Fourier in his work of heat diffusion, the Fourier transform extends the Fourier series to yield a new coordinate basis in terms of sinusoidal functions (e.g., cosines) or analogously complex exponentials. There exists a large number of algorithms to estimate the Fourier transform with a variety of assumptions and differences, e.g. in the arranging of the specific frequencies at which the transform is truly calculated. In the current digital era, the family of algorithms known as fast Fourier transform or FFT (e.g. Cooely-Tukey algorithm and others) have become dominant due to their computational efficiency.The use of Fourier transform is

pervasive, whether explicit or implicit, across almost every scientific realm and fNIRS is no exception. For instance, FT is at the core of most filter designs.

Alternative definition: Fast Fourier Transform (FFT) is an efficient algorithm that computes the Discrete Fourier Transform (DFT) of a sequence of data points. The DFT is a mathematical technique used to transform a time-domain signal into its frequency-domain representation, which can be used to analyze and manipulate the signal.

Synonym:

References:

https://doi.org/10.1109/MSPEC.1967.5217220

Related terms: Fast Fourier Transform

Frequency domain

Definition: A frequency domain of a signal represents the description of the signal with respect to its frequency content instead of time. The signal is thus described as a sum of (a possibly infinite number of) sinusoidal functions (e.g., sines or cosines) in different frequencies and phases (or, equivalently, with complex exponentials). The actual description is the phase and amplitude of each sine.

Alternative definition:

Synonym: Frequency resolved instrumentation

References:

https://doi.org/10.1016/j.neuroimage.2012.03.049

https://doi.org/10.3389/fnins.2020.00300

Related terms: Frequency domain near infrared spectroscopy

IIR Filter

Definition: An IIR (Infinite Impulse Response) filter is a type of digital filter that uses feedback to achieve its filtering effect. It is called "infinite impulse response" because the filter's impulse response does not decay to zero in a finite amount of time, but rather continues indefinitely.The mathematical representation of an IIR filter can be expressed in terms of its transfer function, which relates the input signal to the output signal. The transfer function of an IIR filter can be represented in the z-domain as: $ H(z) = \frac{Y(z)}{X(z)} = \frac{(b0 + b1 z^{-1} + b2 z^{-2} + \ldots + bm z^{-m}}{1 + a1 z^{-1} + a2 z^{-2} + \ldots + an z^{-n}}$ where: $H(z)$ is the transfer function of the IIR filter $X(z)$ is the z-transform of the input signal $Y(z)$ is the z-transform of the output signal $b0, b1, \ldots, bm$ are the filter coefficients of the numerator (feedforward) part of the transfer function $a1, a2, \ldots, an$ are the filter coefficients of the denominator (feedback) part of the transfer function $z^{-1}, z^{-2}, \ldots, z^{-m}, z^{-n}$ are the z-domain delay operators The coefficients $b0, b1, \ldots, bm$ and $a1, a2, \ldots an$, can determine the frequency response and other characteristics of the filter. In general, the order of the filter is equal to the maximum of m and n. The transfer function of an IIR filter can be converted to the time domain using the inverse z-transform, which gives the filter's impulse response. The impulse response of an IIR filter typically decays slowly and does not reach zero, due to the feedback loop in the filter's design. In terms of fNIRS analysis, the Butterworth filter is a commonly used type of IIR filter. It is a type of low-pass filter that provides a maximally flat frequency response in the passband, which means that the gain is constant up to a certain cutoff frequency. The Butterworth filter is often used in fNIRS analysis to remove high-frequency noise from the measured signals, which can be caused by factors such as movement artifacts or electrical interference. Furthermore, it may be helpful to learn about the concept of filter design and how to select appropriate filter parameters, such as the cutoff frequency and filter order, based on the characteristics of the input signal and the desired filtering effect. Additionally, it may be useful to learn about the limitations and potential drawbacks of IIR filters, such as the potential for instability and phase distortion. Additionally, it may be useful to learn about the limitations and potential drawbacks of IIR filters, such as their susceptibility to instability and phase distortion. For instance, a combination of IIR and zero-phase filtering is only suitable for offline analysis, as correcting the nonlinear phase distortion requires access to the entire time series. This allows the data to be processed both forward and backward, effectively eliminating phase distortion.

Alternative definition: An IIR filter requires past output data values in addition to input data. An IIR filter has a frequency response that includes zeros and poles due to having a feedback mechanism that might allow the filter becomes unstable compared to an FIR

filter. The property of infinite impulse response (IIR) applies to many linear time-invariant systems that are distinguished by having an impulse response that does not become exactly zero beyond a given point but instead continues indefinitely.

Synonym:

References:

https://doi.org/10.1109/ICEC.1996.542373

Related terms:

Kalman filter

Definition: A Kalman filter is a mathematical algorithm used to estimate the state of a dynamic system based on noisy measurements. It is a type of recursive filter that updates its estimates of the state and its uncertainty over time as new measurements are obtained. The Kalman filter is based on a probabilistic model of the system, where the state of the system is represented as a random variable and the measurements are also subject to noise. The filter estimates the state of the system by combining the predicted state based on the system dynamics with the measurement information, using a weighted average that gives more weight to measurements that are more reliable.The mathematical representation of a Kalman filter for fNIRS studies is similar to that of a general Kalman filter, but with specific parameters and state variables that are tailored to the characteristics of the fNIRS signal. The state vector of an fNIRS Kalman filter typically includes the changes in concentration of oxygenated hemoglobin (HbO) and deoxygenated hemoglobin (HbR) in each brain region being measured. The state vector at time k is denoted as $x(k) = [HbO(k), HbR(k)]^T $ The measurement vector typically includes the measured optical density changes at each wavelength and each source-detector pair, denoted as $z(k) = [\Delta OD1(k), \Delta OD2(k), \ldots , \Delta ODn(k)]^T $ where $\Delta ODi(k)$ represents the change in optical density at the i-th source-detector pair at time k.

Alternative definition:

Synonym:

References:

https://doi.org/10.1134/S2075108711020076

https://doi.org/10.1109/IMOC.2009.5427541

Related terms:

L1 norm

Definition: The L1 norm is the p=1 norm case of Lebesgue's Lp spaces. Norms are positive mappings $x \rightarrow || x || $ from a vector space X over the field of real or complex numbers into the real numbers that abides by the principle of superposition. Norms are often a measure of an object size and hence they are distance functions (from the origin) e.g. metrics. There exist a myriad of norms with Lebesgue's Lp norms being perhaps the most familiar.The specific case of the L1 norm is a popular choice as a penalty term in regularization techniques to encourage sparse solutions. In fNIRS analysis, the L1 norm has found many uses; for instance in image reconstruction. It has also been used in sparsity regularization, where the goal is to identify the regions of the brain that are most active during a task. Sparsity regularization involves adding a penalty term to the objective function that is minimized when estimating the changes in hemoglobin concentration. The penalty term encourages the solution to have many zero or near-zero coefficients, which indicates that only a few regions of the brain are active during the task.

Alternative definition:

Synonym:

References:

https://encyclopediaofmath.org/wiki/Norm

W. Rudin, "Functional analysis" , McGraw-Hill (1979)

https://doi.org/10.1007/978-3-662-09000-8

Related terms:

Moore-Penrose Pseudoinverse

Definition: Moore-Penrose Pseudoinverse, or simply the Moore-Penrose inverse, is a mathematical operation that produces an inverse of a matrix that may not have a conventional inverse. For a square matrix A, the inverse A^{-1} exists if and only if the determinant of A is non-zero. However, many matrices encountered in practice are not invertible. The pseudoinverse is a generalization of the inverse that can be used for any matrix, regardless of its invertibility (not a square or a full rank matrix).In image reconstruction, to recover the optical properties of the voxels, the computation of the Moore-Penrose Pseudoinverse A^+ is required.Since fNIRS measurements contain different types of noise, A^+ is formulated including Tikhonov regularization to aid in smoothing the noise, as follows: $A^{+} = A^{T} {(A A^{T} + \alpha \mathbf{I})}^{-1}$, $$$A^+ = A^T (AA^T + \alpha \mathbb{1})^{-1} $ where α is the regularization parameter and $\mathbb{1}$ is the iden$ty matrix. It should be noted that Moore-Penrose's is not the only pseudo inverse.

Alternative definition:

Synonym:

References:

https://doi.org/10.1017/S0305004100030401

https://doi.org/10.1063/5.0015512

https://doi.org/10.1117%2F1.JBO.26.5.056001

Related terms: Image reconstruction

Norm

Definition: Norms are positive mappings $x \rightarrow || x || $ from a vector space X over the field of real or complex numbers into the real numbers that abides by the principle of superposition. Norms are often a measure of an object size and hence they are distance functions (from the origin) e.g. metrics. There exist a myriad of norms with Lebesgue's Lp norms being perhaps the most familiar.

Alternative definition:

Synonym:

References:

https://encyclopediaofmath.org/wiki/Norm

W. Rudin, "Functional analysis" , McGraw-Hill (1979)

https://doi.org/10.1007/978-3-662-09000-8

Related terms: L1 Norm

Stratonovich–Kalman–Bucy filter

Definition: The Stratonovich-Kalman-Bucy filter (SKB filter) is a variant of the Kalman filter that is used for estimating the state of a dynamic system in the presence of both process and measurement noise. The SKB filter extends the Kalman filter to systems with nonlinear dynamics by incorporating the concepts of the Stratonovich calculus. The Stratonovich calculus provides a way to handle stochastic differential equations with multiplicative noise, where the noise term is multiplied by the derivative of the state variables.

Alternative definition:

Synonym:

References:

http://dx.doi.org/10.2139/ssrn.2594333

Related terms: Kalman Filter

Wavelet filter

Definition: A wavelet is a waveform of limited duration that has an average value of zero. Some wavelets are defined by a mathematical expression and are drawn as continuous and infinite, called crude wavelets. Before combining with a digital signal, the crude wavelets should be first converted to wavelet filters having a finite number of discrete points. In other words, we evaluate the crude wavelet equation at the desired points in time (usually equispaced) to create the filter values at those times.

Alternative definition: Wavelets are brief wave-like oscillations that are localized. A wavelet filter is a signal processing technique that enables the exclusion of short-time duration patterns captured by the used wavelet. The patterns to be filtered out depend on the wavelet family used and the number of levels of decomposition.

Synonym:

References:

https://doi.org/10.5860/choice.47-0918

Related terms:

Anatomical Directions

Definition: Anatomical directions are the terms that are used to define the location of a region in the body (or brain), usually in relation to another structure. These terms are;Anterior: Front of something Posterior: Back of something Medial: Something close to the midline Mesial: located on the Side of the Brain where the two Hemispheres face each other Lateral: Something located in one of the sides (right or left) Contralateral: Located in the opposite site of a structure Ipsilateral: Located in the same side of a structure Bilateral: Located in both sides of a structure Superior: Above or upper part of something Inferior: Below or lower part of something Rostral: towards the front (mouth/nose; anterior) Caudal: towards the back (tail; posterior) Dorsal: towards the top of the head (like the dorsal fin of a shark; superior; to the back e.g. in the spinal chord) Ventral: towards the bottom of the brain (inferior; or to the stomach e.g. ventral columns of the spinal chord)

Alternative definition: (if applicable)

Synonym:

References: https://doi.org/10.1002/ca.22677

Related terms: Nervous system, Anatomy

Anemia

Definition: Anemia is a haematological disorder that results in reduced capacity to carry oxygen in red blood cells due to a lack in hemoglobin, a lesser amount of hemoglobin per red blood cell or is caused by an overall lack/ dysfunction of red blood cells. Anemia can have different causes and is associated with a range of medical diseases and conditions. A common cause for anemia is a reduced capacity to synthesize sufficient hemoglobin as the oxygen carrying protein, e.g. resulting from a lack of iron, vitamins or malnutrition, or a substantial loss of blood due to major injury.

Alternative definition: (if applicable) Anemia is a condition in which normal hemoglobin content in the blood is reduced, resulting in insufficient oxygen supply to the body. This is mainly caused by iron deficiency and blood loss.

Synonym:

References:

https://doi.org/10.1016/S2214-109X(22)00084-5

https://doi.org/10.1016/j.tmrv.2020.07.003

Related terms:

Blood flow

Definition: Blood flow (BF) refers to the amount of blood that flows through vessels (e.g. arteries, capillaries, veins). It is a rate measured in ml/100g/min. Blood flow is determined by the difference between mean arterial (MAP) and central venous pressure (CVP) and depends on the total peripheral resistance (TPR): $BF = \frac{MAP - CVP}{TPR} Blood flow can be increased by increasing the volume (increase in vessel diameter) and/or the velocity. Blood flow can also be regulated peripherally by altering the arterial resistance. Blood flow thus depends on the particular vessel where it is measured (e.g. it is larger in arteries compared to capillaries, or veins).

Alternative definition:

Synonym:

References: P. Morris, D. Warriner, and A. Morton. Eureka: Cardiovascular Medicine. Eureka (London, England). JP Medical, 2015.

https://doi.org/10.3389/fphys.2021.747759

Related terms: Blood volume, Blood pressure, Metabolism, Scalp blood flow, hemodynamic response, Blood supply, Perfusion

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Blood oxygenation

Definition: Blood oxygenation refers to the total content of oxygen in a given volume of blood.

Alternative definition: Amount of oxygen present in arterial or venous blood; while the measure of oxygen present in the vascular tissue or microvascular bed is referred to as tissue oxygenation.

Synonym: (Blood) n

References:

Related terms: Oxygen Deficiency, Hypoxia, Hyperoxia

Blood oxygenation level dependent (BOLD) contrast

Definition: Bold oxygenation level dependent contrast refers to intravascular and extravascular relaxation time T_2 (magnetic field inhomogeneity) and relaxation time T_2 contrast changes that result from variations in the deoxyhemoglobin concentration of blood. The blood oxygenation level dependent contrast mechanism (T_2) is widely used for functional MRI because changes in neuronal activity level normally result in changes in oxyhemoglobin and deoxyhemoglobin concentration. Functional MRI is able to capture the changes only in deoxyhemoglobin concentration due to it being a paramagnetic material in blood. There is also a (substantially smaller) effect of overall blood volume in a voxel.

Alternative definition:

Synonym: Blood Oxygen Level Dependent Response (BOLD Response)

References:

https://doi.org/10.1073%2Fpnas.87.24.9868b

Related terms: Hemodynamic response function, (functional) magnetic resonance imaging

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Blood oxygen saturation

Definition: Blood oxygen saturation is the concentration of oxygen-bound hemoglobin relative to the total concentration of

hemoglobin in the blood, usually measured as a percentage. Normal arterial blood oxygen saturation is approx. between 95%-100%.

Alternative definition: The percentage of hemoglobin binding to oxygen in the blood.

Synonym: (Blood) Oxygen Saturation

References:

Related terms: Oxygen Deficiency, Hypoxia, Hyperoxia

Blood pressure

Definition: Blood pressure is the force exerted by the blood against the inner walls of the blood vessels. It is determined by the blood volume ejected by the heart into the arteries, the elasticity of the walls of the arteries, and the rate at which the blood flows out of the arteries. It is greatest in the arteries and decreases as blood flows through the capillaries. Systolic pressure is the maximum blood pressure during contraction of the ventricles; diastolic pressure is the minimum pressure recorded just prior to the next contraction.

Alternative definition:

Synonym:

References: https://doi.org/10.1186/s13054-018-2171-1

Related terms: Systolic and diastolic pressure, Mayer waves

Blood volume pulse

Definition: The blood volume pulse is the change in volume of blood over a given period of time. Also described as the pulsatile component of the blood pressure, i.e. the wave between systolic and diastolic blood-pressure. For fNIRS signals it should be apparent in the frequency range of the heart rate consisting of the blood volume pulse (BVP), i.e. a signal change with a specific shape. The BVP is mainly caused by the vascular blood volume increase during systole. The shape of the BVP depends on several factors, including the vascular blood volume content, the vascular compliance and resistance.

Alternative definition:

Synonym:

References: https://doi.org/10.1186/s13054-018-2171-1

Related terms: Heart Rate Variability (HRV), blood flow

Brain Computer Interface

Definition: A brain computer interface (BCI) describes a direct communication pathway between the brain activity and an external device, for instance, a computer, a robot or a prosthesis. It is a neurotechnological input system that conveys machine control independent of speech and movement. Since BCIs work completely without muscle activation, BCIs open up new operating options from which physically handicapped people, among others, can benefit.A communication system comprising hardware and software that allows humans to interact with their environment without using peripheral nerves or muscles. It is a closed loop system that basically includes neural signal pre-processing, feature extraction, machine learning based classification and external control steps.

Alternative definition: BCIs are a subset of brain machine interfaces (BMI). A BMI is a communication system in which messages or commands from the brain are conveyed to the external world

Synonym:

References: https://doi.org/10.3390/bios11100389

https://doi.org/10.3389%2Ffnhum.2015.00003

https://doi.org/10.1080/2326263X.2021.1969789

https://doi.org/10.3390/s120201211

https://doi.org/10.1016/j.mayocp.2011.12.008

Related terms: Biofeedback, Neurofeedback, Neuromodulation, Brain Machine Interface (BMI), Brain Computer Communication (BCC), Brain Computer Link (BCL)

Cerebral autoregulation

Definition: The process by which a largely constant blood flow in the brain is maintained irrespective of posture and systemic blood pressure. It includes mechanisms related to muscular, neural or metabolic activity, which influence small arteries and arteriole diameter.. These mechanisms allow the brain to receive a steady supply of arterial blood, which transports oxygen, nutrients and other substances (e.g. hormones) that are necessary for physiological brain function.

Alternative definition:

Synonym:

References: https://doi.org/10.3390/bios11100389

https://doi.org/10.3389%2Ffnhum.2015.00003

https://doi.org/10.1080/2326263X.2021.1969789

https://doi.org/10.3390/s120201211

https://doi.org/10.1016/j.mayocp.2011.12.008

Related terms: Neurovascular coupling, CO2 reactivity, Mayer waves

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Cerebral blood flow

Definition: Cerebral blood flow (CBF) is the amount of blood that passes through a local area of the brain in a given time. It is usually measured in milliliters of blood/100 grams of the brain tissue/minute. It can be altered by altering the blood volume and/or the blood flow velocity. There is a relationship between cerebral blood volume and cerebral blood flow: $CBF = (\frac{CBV}{0.80})^{\frac{1}{0.38}}

Alternative definition:

Synonym:

References: https://doi.org/10.1152/physrev.00022.2020

https://doi.org/10.1161/01.str.5.5.630

https://doi.org/10.1117/1.NPh.3.3.031411

Related terms: Blood flow, Diffuse Correlation Spectroscopy (DCS)

Cerebral blood volume

Definition: Cerebral blood volume is the total amount of blood in the brain. It is usually expressed in $ \frac{ml}{100gr} $ of tissue. The total hemoglobin (HbT) is related to cerebral blood volume by cerebral haematocrit by: $ CBV\left[\frac{10^{-3}l}{100gr} \right] = \frac{10^{-5}M}{\rho \ast H \ast R} HbT \left[\frac{10^{-3}l}{100gr} \right]$ Where: ρ is the brain density. M is the molecular weight of the hemoglobin. H is the large vessel hemodynamic concentration. R is the cerebral to large vessels hematocrit ratio. If the hematocrit is considered to remain constant during hemodynamic response to activation, then HbT is proportional to cerebral blood volume. CBV is a critical physiological indicator of tissue viability and vascular reactivity as CBV changes are directly linked to the regulation of cerebral blood flow under pathophysiological conditions

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2004.07.013

https://doi.org/10.1161/01.str.5.5.630

https://doi.org/10.1152/jappl.1990.68.3.1086

Related terms:

Cerebral cortex

Definition: The outer layer of the brain, composed of neurons and glia organized into vertically superimposed cortical layers, as well as cortical regions and lobes (frontal, temporal, parietal, occipital) defined over the surface. The largest part of the cortex is the 'isocortex', with 6 layers, while the allocortex (e.g., the hippocampal gyrus) has only 3 layers. The mature adult cerebral cortex is strongly folded, resulting in sulci (grooves) and gyri (ridges), which often serve as reference points to define cortical regions and demarcate the four lobes. One of the most widely used mapping of the human cerebral cortex is according to the Brodmann's Areas based on surface anatomy as well as cytoarchitectonics.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms: Neocortex, Cortex, Cerebrum, Gray matter

Cerebral metabolic rate of oxygen

Definition: Cerebral metabolic rate of oxygen is the oxygen consumption of the brain determined by the difference of oxygen flowing into and out of a certain brain region. Together with the cerebral blood flow, it determines the level of blood oxygenation. There is a way to estimate cerebral metabolic rate of oxygen from cerebral blood flow, deoxygenated hemoglobin and oxygenated hemoglobin. If the arterial oxygen saturation is assumed to be 1, then the relative change in cerebral metabolic rate of oxygen is given by : $\left(1 + \frac{\Delta CMRO_{2}}{CMRO_{2,0}}\right) = \frac{\left(1 + \frac{\Delta CBF}{CBF_{0}}\right)\left(1 + \gamma R\frac{\Delta HHb}{HHb_{0}}\right)}{\left(1 + \gamma T\frac{\Delta HbT}{HbT_{0}}\right)}$ where the sub index 0 represent baseline values and $\Delta(. . .)$ simply represent the variation of the respective parameter. Finally, γR and γT represent the correspondent factors which relate the fractional hemoglobin changes in the venous compartment to those across all vascular components. The parameters γR and γT can be calculated as: $\gamma R = \frac{\left(\frac{\Delta HHb_{v}}{HHb_{v,0}}\right)}{\left(\frac{\Delta HHb}{HHb_{0}}\right)}$ $\gamma T = \frac{\left(\frac{\Delta HbT_{v}}{HbT_{v,0}}\right)}{\left(\frac{\Delta HbT}{HbT_{0}}\right)}$ where: ΔHHb_{v} is the variation of deoxygenated hemoglobin concentration in the localized venous compartment. $ HHb_{v,0} $ is the baseline deoxygenated hemoglobin concentration in the localized venous compartment. $ \Delta HbT_{v} $ is the variation of total hemoglobin concentration in the localized venous compartment. $ HbT_{v,0} $ is the baseline total hemoglobin concentration in the localized venous compartment.

Alternative definition:

Synonym:

References: https://doi.org/10.1088/0031-9155/48/15/311

https://doi.org/10.1016/j.neuroimage.2012.01.040

https://doi.org/10.1016/j.neuroimage.2004.07.013

https://doi.org/10.1016/j.neuroimage.2023.120189

Related terms:

Cerebral Tissue Oxygenation Saturation

Definition: Cerebral tissue oxygenation saturation (SctO2) is a measurement of the level of oxygen saturation in the cerebral tissue of the brain. It is typically expressed as a percentage and can be obtained by some approaches with near-infrared spectroscopy (NIRS) technology. SctO2 reflects the proportion of hemoglobin molecules in the cortical blood vessels that are bound to oxygen, and it provides valuable information about the oxygen supply to the brain. Monitoring SctO2 is important in various clinical settings, including critical care, surgery, and neonatology, as changes in SctO2 can indicate conditions such as cerebral hypoxia, ischemia, and reperfusion injury, which require prompt clinical interventions to improve brain perfusion and oxygenation.

Alternative definition:

Synonym:

References: https://doi.org/10.1088/0031-9155/48/15/311

https://doi.org/10.1016/j.neuroimage.2012.01.040

https://doi.org/10.1016/j.neuroimage.2004.07.013

https://doi.org/10.1016/j.neuroimage.2023.120189

Related terms:

Cerebrovascular reactivity

Definition: Cerebrovascular reactivity (CVR) is the ability of blood vessels to change their diameter to adjust tissue blood supply based on tissue demand. One important modulator is partial CO$_2$ pressure in the blood. CVR is a crucial regulatory component of the neurovascular coupling system, ensuring sufficient blood supply and oxygenation to the brain. It is often assessed using CO$_2$ challenges (e.g. increase in partial CO$_2$ pressure through forced CO$_2$ inspiration). CVR can be investigated by measuring the change in cerebral blood flow (CBF) or cerebral blood volume (CBV). CVR is a useful index for the assessment of vascular health in several pathologies, including stroke and neurodegenerative disorders such as Alzheimer's and Parkinson's diseases.

Alternative definition:

Synonym:

References: https://doi.org/10.3389/fphys.2021.643468/full

Related terms: Cerebral blood flow, Cerebral blood volume

Chromophore

Definition: A chromophore is a molecule that absorbs light within a specific wavelength range, spanning from ultraviolet to infrared light. Within the near-infrared spectrum, the primary chromophores in biological tissues include water, hemoglobin, lipids, and cytochrome oxidase. Notably, light achieves its deepest penetration into tissue at wavelengths approximately between 700 and 900 nm. Functional Near-Infrared Spectroscopy (fNIRS) employs multiple wavelengths in order to sensitively distinguish between changes in the concentrations of oxyhemoglobin and deoxyhemoglobin, providing valuable insights into tissue oxygenation and, by extension, neural activity.

Alternative definition:

Synonym:

References: https://doi.org/10.1176/jnp.2010.22.4.iv

https://doi.org/10.1117/1.nph.9.4.040601

https://doi.org/10.1364/boe.6.000933

https://doi.org/10.5772/32493

Related terms: hemoglobin, cytochrome, wavelength

Connectivity

Definition: Connectivity refers to the connections between brain regions that are spatially distributed but anatomically or functionally connected subserving information processing. There are three related forms of connectivity: (i) anatomical connectivity, (ii) functional connectivity and (iii) effective connectivity. Anatomical connectivity (AC) refers to the structural connections between brain regions (i.e., connectome). Functional connectivity (FC) refers to brain regions with a temporal dependency activation pattern (evaluated via statistical analysis). Effective connectivity (EC) refers to the causal role of a brain region activation over another one.

Alternative definition: (if applicable)

Synonym:

References:

https://doi.org/10.1155/2012/412512

Related terms: anatomical connectivity, functional connectivity, effective connectivity

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Cortex

Definition: Cortex refers to the outermost, superficial layer of some organs (e.g. the brain but also the kidney). The brain's cortex is referred to as cerebral cortex, and it is often the target of fNIRS investigations. The cortex of the cerebellum is referred to as cerebellar cortex.

Alternative definition:

Synonym: cortical surface, gray matter

References: M.F. Bear, B.W. Connors, and M.A. Paradiso. Neuroscience: Exploring the brain. Neuroscience: Exploring the Brain. Lippincott Williams & Wilkins, 2007.https://psycnet.apa.org/record/2007-18995-000

Related terms: Cerebral Cortex, Cerebellar Cortex

Cortical (cerebral) oxygen saturation

Definition: Cortical oxygen saturation is the regional cortical hemoglobin saturation, measured by cerebral tissue oximeters based on near infrared spectroscopy methods, in the small vessels (<1 mm in diameter) of the cerebral cortex such as the capillary, arteriolar and venular bed.

Alternative definition:

Synonym: StO2, rSO2, SctO2, or rStO2

References: https://doi.org/10.1053/j.jvca.2021.07.015

Related terms: Regional cerebral tissue hemoglobin oxygen saturation. Regional cerebral (oxygen) saturation. Brain oxygen saturation. Cerebral oxygenation

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Cytochrome-c-Oxidase

Definition: Cytochrome-c-Oxidase is an enzyme complex that plays a central role in the mitochondrial electron transport cascade leading to adenosine triphosphate (ATP) synthesis by oxidative phosphorylation. Its activity depends on energy demands. Cytochrome-c-Oxidase redox state can be measured with broadband NIRS.

Alternative definition: Check doi: 10.1098/rstb.1997.0048 for complete alternative definition.

Synonym: aa3, CuA, CytC

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1007%2F978-3-319-55231-6_19

https://doi.org/10.1098/rstb.1997.0048

Related terms: bNIRS

Deoxygenated Hemoglobin

Definition: Deoxygenated hemoglobin is a form of the hemoglobin molecule that has released its bound oxygen molecule(s) and is therefore carrying no oxygen. Hemoglobin is the protein in red blood cells that carries oxygen to the body's tissues. When oxygen binds to hemoglobin, it changes the conformation of the protein, making it more compact and changing its color from blue to red, which is why oxygenated blood appears bright red. Conversely, when the oxygen molecules detach from hemoglobin, the protein's conformation changes back to its original state, making it more open and revealing a bluish-purple hue, which is why deoxygenated blood appears dark red. Measuring the amount of deoxygenated hemoglobin in the blood can provide information about oxygen delivery and utilization in different organs and tissues, which can be useful in various clinical and experimental settings.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1007%2F978-3-319-55231-6_19

https://doi.org/10.1098/rstb.1997.0048

Related terms: Oxygenated Hemoglobin, Total Hemoglobin

Differential Hemoglobin

Definition: Differential Hemoglobin is calculated as the difference between HbO2 and HbR, Hbdiff = HbO2 – HbR.

Alternative definition:

Synonym:

References:

https://doi.org/10.1007/978-0-387-85998-9_47,

https://doi.org/10.1016/S0166-2236(97)01132-6,

https://doi.org/10.1117/1.NPh.9.2.025001

Related terms: Total Hemoglobin, Deoxygenated Hemoglobin, Oxygenated Hemoglobin

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Effective connectivity

Definition: The effective connectivity is the causal influences that neural units exert over another (as opposed to functional connectivity that only describes associative relations between neuronal units). Several approaches are available for detecting and quantifying effective connectivity. These techniques allow researchers to examine how different regions of the brain are connected and often to estimate the strength and directionality of these connections, and in the case of dynamic connectivity, also their change over time or in response to different experimental manipulations.

Alternative definition:

Synonym:

References:

https://doi.org/10.1089/brain.2011.0008

https://doi.org/10.1007/s11517-011-0739-x.

https://doi.org/10.1002/hbm.460010108

Related terms: Anatomical/Structural connectivity, Functional connectivity, Granger causality, dynamic causal modeling, partial directed coherence, directed transfer function, transfer entropy, dynamic functional connectivity, dynamic effective connectivity

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Extracerebral

Definition: Extracerebral means outside of the brain (cerebrum). In fNIRS research, the term is used either to describe the structures in the probed tissue volume, which is not part of the organ of interest, such as skin, skull and CSF. The extracerebral 'contamination' of the fNIRS signal is related to systemic blood flow and volume changes that occur in scalp, skull, or other extracerebral tissues. Extracerebral signals can mask the cerebral signals measured by fNIRS.

Alternative definition:

Synonym: extra-cerebral

References: not applicable

Related terms: Noise, Physiological Noise, Extracerebral Systemic Activity, Short-distance channels

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Functional connectivity

Definition: Functional connectivity (FC) is defined as the statistical dependency between two or more time series originating from different brain regions. FC analyses are mostly conducted to investigate how neural activity is correlated in time between brain regions or networks. FC can be calculated during different states (e.g., during rest or during performance of a task). In task-related contexts, it is important to consider the effect of task-related activity in resulting FC measures, as an external signal or stimulus can result in similar temporal profiles of FC across regions without these regions being connected per se.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2018.01.053

https://doi.org/10.3389/fnsys.2015.00175

https://doi.org/10.1117/1.3462973

https://doi.org/10.1162/jocn_a_01828

Related terms: Resting-state functional connectivity (rsFC), Task-state functional connectivity (tsFC), resting state networks (RSN), dynamic functional connectivity, connectivity

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Functional hyperemia

Definition: Functional hyperemia is an increase in blood flow in response to neural metabolic activity. In the brain, this mechanism ensures sufficient supply of oxygen and nutrients to active regions during periods of heightened neural activity. It is crucial for normal physiological brain function and is disrupted in pathological processes, including neurological (e.g. stroke, traumatic brain injury, and neurodegenerative diseases) and metabolic (e.g. diabetes) diseases.

Alternative definition:

Synonym:

References: https://doi.org/10.1177%2F1073858417703033 https://doi.org/10.1161/01.STR.29.1.229

Related terms: Hyperemia

Functional Localization

Definition: Functional localization refers to the process of using a well-defined task to decide which brain regions are selective, i.e. show statistically significant activation, for a particular function, and then testing if the same brain regions are engaged in a second task. For example, participants perform a finger tapping task to assess the location of motor functions and the channel(s) with the strongest motor response(s) in each participant is (are) taken as that person's functional ROI. The same participants then perform a motor planning task and the brain response to motor planning is assessed ONLY in the functional ROI. Note the functional ROI is defined by the first task and could be in a different location in each participant. This method is common in fMRI but less common in fNIRS.

Alternative definition:

Synonym:

References: https://doi.org/10.1177%2F1073858417703033 https://doi.org/10.1161/01.STR.29.1.229

Related terms: Hyperemia

Gray Matter

Definition: Gray matter is the brain tissue which contains the neuronal cell bodies and synapses. The largest part is in the cerebral cortex, but the basal ganglia and thalamus are also gray matter structures which are embedded in the white matter. The cerebrum, brainstem and cerebellum, and throughout the spinal cord have gray matter. It is distributed at the surface of the cerebral hemispheres (cerebral cortex) and of the cerebellum (cerebellar cortex). It is distinguished from white matter, which mostly consists of (myelinated) axons, and derives its whitish color from the color of myelin.

Alternative definition: (if applicable)

Synonym:

References:

Mercadante AA, Tadi P. Neuroanatomy, Gray Matter (2023)Treasure Island (FL): StatPearls Publishing; PMID: 31990494. https://pubmed.ncbi.nlm.nih.gov/31990494/

https://doi.org/10.1002/glia.23614

Related terms: white matter

Hemisphere

Definition: Hemisphere refers to a half of the cerebrum. The two hemispheres have slight anatomical differences and slightly distinct functional specializations. The right hemisphere controls the left side of the body and vice versa. Such lateralization can readily be measured using fNIRS for many neural functions.

Alternative definition:

Synonym: Right lobe

References: E. Kandel. Principles of Neural Science, Fifth Edition. Principles of Neural Science. McGraw-Hill Education, 2013.

Related terms: Lateralization, Lobe, Cerebrum

Hemodynamic response

Definition: Hemodynamic response is a change in blood flow in response to an increase in local metabolic demands due to an increase in neuronal activity. In the measured fNIRS signal, this is reflected as a change in oxy- and deoxy-hemoglobin concentrations. Typically the blood flow response overcompensates the demand leading to a focal hyperoxygenation in the activated area. The peak of the hemodynamic response is detectable by NIRS at about 6 seconds (4-8 s) after the onset of the event. Hemodynamic response is typically characterized by a large increase in Oxy-Hb and a smaller decrease in the concentration of deoxygenated hemoglobin (but may - depending on the measurement area - also show no change or even increase during a hemodynamic response) resulting in the characteristic anticorrelated signal structure of oxy- and deoxy-hemoglobin. Features of the hemodynamic response function (HRF) have been shown to change with age or disease.

Alternative definition:

Synonym: hemodynamic responses, hemodynamic responses

References: M.A. Arbib and J.J. Bonaiuto. From Neuron to Cognition Via Computational Neuroscience. Computational Neuroscience Series. MIT Press, 2016.

https://doi.org/10.1016/j.neuroimage.2005.08.065

https://doi.org/10.1016/j.neuroimage.2007.02.035

https://doi.org/10.1088/0031-9155/47/7/309

Related terms: Blood oxygen level dependent response, neurovascular coupling, hemodynamic response function (HRF), initial dip

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Hemoglobin

Definition: Hemoglobin is the oxygen-carrying pigment and the predominant protein in the red blood cells that is responsible for delivery of oxygen to the tissues. Each hemoglobin molecule is made up of four subunits (globins) each containing a heme group. Heme contains iron, which gives a red color to the molecule. Hemoglobin forms an unstable, reversible bond with oxygen. In its oxygenated state it is called oxyhemoglobin (O2Hb) and is bright red. In its reduced state it is called deoxyhemoglobin (HHb) and is purple-blue. O2Hb and HHb have different magnetic and optical properties that give rise to functional magnetic resonance imaging (fMRI) and functional near-infrared spectroscopy (fNIRS) signals. O2Hb is diamagnetic (i.e. it shows a weak repulsion in magnetic fields) and has an optical absorption around 660nm. In contrast, HHb is paramagnetic (i.e. it shows a weak attraction in magnetic fields) and has an optical absorption around 760 nm. Hemoglobin concentrations in the blood depend on physiological processes and are thus affected in certain diseases (e.g. malnourishment) that can result in anemia.

Alternative definition:

Synonym:

References: F.G. Ashby. Statistical Analysis of FMRI Data. EBSCO ebook academic collection. MIT Press, 2011.

Billett HH. Hemoglobin and Hematocrit. In: Walker HK, Hall WD, Hurst JW, editors. Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd edition. Boston: Butterworths; 1990. https://www.ncbi.nlm.nih.gov/books/NBK259/

https://doi.org/10.1038/npjparkd.2016.21

Related terms: Oxyhemoglobin, Deoxyhemoglobin, Total Hemoglobin, Anaemia

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Homologous Connectivity

Definition: Homologous connectivity refers to the connectivity between corresponding brain regions or areas in the left and right hemispheres. They are often referred to as "mirror" areas due to their similar structure and function: for example, the correlation between activity in the left dorsolateral prefrontal cortex and the right dorsolateral prefrontal cortex.

Alternative definition:

Synonym: Inter-hemispheric (homologous) Connectivity, Homotopic Connectivity

References: https://doi.org/10.1038/s41598-019-40188-3

Related terms: Bilateral Connectivity

Initial dip

Definition: The initial dip describes a transient negative response that can be sometimes observed in blood-oxygenation level-dependent (BOLD) / hemodynamic signals. It is assumed to reflect the preliminary stages of the neural metabolic response that causes a transient decrease in oxygenated hemoglobin just prior to the much larger ensuing hemodynamic response leading to an increase in focal oxygenation. The initial dip has been subject to substantial debate because it cannot always be observed. Many factors likely contribute to whether it appears and to what degree, including physiological conditions, participant age, experimental methodologies, species, regions, data analysis. Nethertheless, the initial dip is modeled as part of the canonical hemodynamic response function for BOLD fMRI analyses.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2012.03.005

https://doi.org/10.1016/j.neuroimage.2012.03.005

https://doi.org/10.3389/fnbot.2018.00069

https://doi.org/10.1364/BOE.8.000367

Related terms: blood-oxygenation level-dependent (BOLD) response, hemodynamic response, hemodynamic response function

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Inter-personal neural synchrony

Definition: Synchronized fluctuations of brain signals between two or more individuals observed during social interaction or when the individuals participate in joint tasks. fNIRS naturally lends itself to the characterization of inter-personal neural synchrony because of its ease of recording when two individuals are interacting. The typical setup to measure inter-personal neural synchrony is hyperscanning.

Alternative definition:

Synonym: Inter-personal brain synchrony; Brain-to-brain synchrony, inter-subject connectivity

References: https://doi.org/10.1093/scan/nsaa115 https://doi.org/10.1016/j.neuroimage.2021.118263 https://doi.org/10.1016/j.tics.2020.01.006

10.1016/j.neubiorev.2023.105042

Related terms: Hyperscanning

Intracerebral

Definition: Occurring in, or situated within the cerebrum as opposed to in the surface vasculature or elsewhere outside the brain.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms: Intercerebral

Intracranial

Definition: Intracranial refers to something situated or occurring in the skull (cranium).

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms:

Inverted Hemodynamic Response

Definition: The inverted hemodynamic response is a response where oxy-Hb decreases and deoxy-Hb increases in response to a stimulus. The inverted hemodynamic response is occasionally observed in adult participants, and somewhat more frequently in developmental populations. The exact reasons for its occurrence are not fully clear, it may be related to individual variability, age and the immaturity of the hemodynamic response, in particular in infants, but it is sometimes also related to the experimental task or stimuli, (e.g. when the baseline stimuli trigger a stronger response than the experimental stimuli), or to systemic changes (e.g. decrease in partial pressure of CO2).

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.dcn.2018.01.009

https://doi.org/10.1016/j.neuroimage.2016.08.058

Related terms: negative BOLD response

Mayer waves

Definition: Mayer waves are slow oscillations of arterial pressure occurring spontaneously at a frequency lower than respiration $\sim$ 0.1 Hz in humans). They are tightly coupled with synchronous oscillations of efferent sympathetic nervous activity and are almost invariably enhanced during states of sympathetic activation. Mayer waves are correlated with heart rate variability. They are strongest in adult participants in a sitting or standing position, whereas they are attenuated in the supine position as well as in infants and young children.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.cardiores.2005.11.008

https://doi.org/10.1117/1.NPh.8.4.041001

https://doi.org/10.1142/S0129065720500033

Related terms: arterial blood pressure oscillations, systemic activity, filtering

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Melanin

Definition: Melanin, a poly-indolequinone biopolymer, is a high refractive index brown-black pigment produced and stored by

melanosomes, organelles of the melanocytes at the base of the epidermis. Melanin is composed of nanoparticles that are 30–50 nm in size, in which melanin monomers are cross-linked together and form stacking structures. Melanin absorbs light in the UV, visible, and near-infrared regions and protects tissues by scattering or dissipating light. Darker skin tones have significantly larger and more concentrated melanosomes that increase the absorption cross section of melanin resulting in enhanced light absorption. Extracranial contamination (including skin melanin concentration) do not affect NIRS measurements, since the concentration of melanin remains constant over the measuring period. It thus affects noise level, but not the changes in optical properties due to the hemodynamic response.

Alternative definition:

Synonym:

References: https://doi.org/10.1152/physrev.00059.2017

https://doi.org/10.3389/fnins.2023.1086208

Related terms:

Metabolism

Definition: Metabolism is the total of all organic processes (or chemical changes) taking place in a cell or organism that produce the energy and basic materials that are necessary to sustain life. Cellular metabolism can be divided into two categories: anabolism which entails the construction of complex organic molecules from simpler precursors, and catabolism which involves the breakdown of complex substances into simpler molecules. The adjective of metabolism is metabolic.

Alternative definition:

Synonym: metabolic process

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1038/098389b0

Sánchez López de Nava A, Raja A. Physiology, Metabolism. (2022) Treasure Island (FL): StatPearls Publishing PMID: 31536296.https://pubmed.ncbi.nlm.nih.gov/31536296/

Related terms: catabolism, anabolism

Montreal Neurological Institute template

Definition: A standard set of 3 coordinates in x- y and z-direction developed at the Montreal Neurological Institute (MNI) that reports, as spatial locations in the brain, the results of voxel-based analysis. These coordinates were obtained by spatially co-registering 152 brain images acquired from healthy participants.

Alternative definition:

Synonym:

References:

https://doi.org/10.1017/9781316105771

Related terms: Talairach coordinates

Negative BOLD response

Definition: Relative temporal decrease in BOLD contrast (stemming from increases in proportion of deoxygenated hemoglobin) in specific areas of the brain. Converging evidence indicates that the negative BOLD response can be interpreted as a decrease in

neuronal activity below baseline (e.g. rest) levels. However, it is possible that it originates from a different neurovascular coupling mechanism compared to a positive BOLD response.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/S0896-6273(02)01138-8 ; https://doi.org/10.1152/jn.01199.2011

https://doi.org/10.1016/j.neuroimage.2014.02.029

https://doi.org/10.1016/j.neuroimage.2013.10.055

https://doi.org/10.1016/j.cub.2016.12.028

Related terms: Inverted Hemodynamic Response

Neural Activity

Definition: Neural activity refers to the firing and discharge of action potentials by neurons leading to electrophysiological currents and transmissions in the central nervous system (CNS) and peripheral nervous system (PNS) in order to convey information.

Alternative definition:

Synonym:

References: Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K., & Walter, P. (2002). General principles of cell communication. In Molecular Biology of the Cell. 4th edition. Garland Science.

Related terms:

Neurofeedback

Definition: In neurofeedback, the participant's brain activity is measured (e.g., with fNIRS fMRI or EEG), processed and fed back to the user in real time. In this way, selected features of brain activity are made perceptible to the participant. As a result, participants can learn to modify their brain activity depending on the feedback, and thus directly change specific neural correlates putatively underlying a specific behavior, function or symptom. Neurofeedback training can be implemented in an explicit (i.e. with specific task instructions) or in an implicit way. Neurofeedback has been applied in many clinical areas and is investigated for its potential in alleviating symptoms in a range of psychiatric and neurological diseases.

Alternative definition:

Synonym:

References: https://doi.org/10.1038/nrn.2016.164

https://doi.org/10.15412%2FJ.BCN.03070208

https://doi.org/10.1016/j.neurol.2021.08.004

Related terms: Biofeedback, Brain Computer Interface, real-time

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Neuroimaging

Definition: Neuroimaging is a field of research that uses imaging technology to examine the structure and functions of the central nervous system. There are two main categories of neuroimaging tools: Structural imaging that quantifies the anatomy/morphology of the brain (e.g. voxel-based morphometry) and functional imaging that measures the functioning of the brain (e.g. EEG, fMRI, fNIRS). Moreover Imaging technologies differ with regard to the response assessed, that is the electrophysiological, the hemodynamic and/or the metabolic response.

Alternative definition:

Synonym:

References: https://doi.org/10.3389/fneur.2020.00257

https://doi.org/10.31887%2FDCNS.2009.11.4%2Fmbrammer

Related terms: (functional/structural) Magnetic Resonance Imaging ((f)MRI/(s)MRI), Electroencephalography (EEG), functional Near-Infrared Spectroscopy (fNIRS), Magnetencephalography (MEG), Positron Emission Tomography (PET), Computerized Tomography (CT)

Neurometabolic coupling

Definition: The neurovascular and neurometabolic (NMC) couplings connect cerebral activity, blood flow, and metabolism. This interconnection is used for instance in fMRI and fNIRS. The mechanisms underlying the NVC are complex. Astrocytes adjust energy production to neuronal energy needs through different mechanisms grouped under the term "neurometabolic coupling" (NMC). These mechanisms of coupling are particularly important to ensure normal synaptic functioning when neurons undergo rapid and repetitive changes in the firing rate. Investigations into brain energy metabolism have been mainly focused on glucose consumption, lactate production and glycogen metabolism. Lactate is transferred from astrocytes to neurons to match the neuronal energetic needs, and to provide signals that modulate neuronal functions, including excitability, plasticity and memory consolidation. Consequently, neurons and astrocytes show tight metabolic coupling.

Alternative definition:

Synonym:

References: https://doi.org/10.1111/jnc.13143

Related terms:

Neuron

Definition: Neurons are the main information-processing cells of the nervous system along with supporting cells such as glial cells. Neurons have a cell body, dendrites and axons. Dendrites receive synaptic information from other neurons by transmitters. When the potential change at the axon-hill reaches a critical threshold the cell launches an action potential travelling through the axon which has synaptic connections to the dendrites of other neurons. Most neurons thus use action potentials to send signals over a distance via axons, and neurons communicate with one another using synaptic transmission. While dendritic potential changes add up, the action potential is either generated or not (all- or - nothing principle).

Alternative definition:

Synonym:

References: M.F. Bear, B.W. Connors, and M.A. Paradiso. Neuroscience: Exploring the brain. Neuroscience: Exploring the Brain. Lippincott Williams & Wilkins, 2007

https://doi.org/10.1002/cne.24040

https://doi.org/10.1038/nrn.2018.19

https://doi.org/10.1016/j.neuroscience.2015.12.007

Related terms:

Neurovascular coupling

Definition: Neurovascular coupling is a complex physiological process that regulates blood flow and oxygen delivery to the neuronal tissue during functional activity and is related to the neurovascular unit. The latter comprises the local vasculature , neurons, and astrocytes. A gross oversimplification can be summarized as follows: neural activation increases oxygen demand.

Following arterial endothelium signaling, the regional lood flow is increased. This results in an increase in the cerebral blood flow and cerebral blood volume. Larger increases in cerebral blood volume compared to the regional oxygen consumption results in an increase in blood oxygenation in the region. Neurovascular coupling can be compromised in brain regions that are affected by pathological processes (e.g. inflammation, lesions), which should be considered in the interpretation of hemodynamic brain imaging data of certain patient populations (e.g. traumatic brain injury, or stroke).

Alternative definition: Optical density or absorbance is the ability of a material to transmit light through it. It is affected by the wavelength of light. At the same time, absorption is the transfer of wave energy when the wave passes through a medium.

Synonym:

References: doi: 10.1117/1.JBO.26.10.100901; DOI:10.1152/japplphysiol.01217.2001

doi: 10.1038/s41598-022-06082-1

https://doi.org/10.3390/jfmk4020028

Related terms: Light Intensity

Oxidation

Definition: Oxidation is a chemical reaction in which atoms lose their electron(s).

Alternative definition:

Synonym: Oxidation

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms:

Oxidation state of the cytochrome-c-oxidase

Definition: The enzyme cytochrome-c-oxidase (CCO) is a transmembrane protein in mitochondria - a vital cell organelle - and the last part of the respiratory electron transport chain. As such CCO is a central component to maintain the electrochemical transmembrane gradient of mitochondria, which is needed for the core enzyme involved in energy supply of cells, the ATP-Synthase. Changes in cellular oxygen utilization can be measured by the oxidation state of CCO. Specifically, the oxidation state of CCO (oxCCO) can be detected using multi-wavelength or broadband NIRS. In fact, one of the copper sites of CCO dominates the absorption spectrum in the NIR region, with a strong peak in the oxidized form centered around 830 to 840 nm. The difference between these absorption spectra (oxidized-reduced CCO) can be used to monitor changes in the redox states of the mitochondrial proteins as a prox of brain metabolism. In contrast to changes in hemoglobin oxygenation, oxCCO is cell-specific and not affected by systemic, extracerebral fluctuations. It is thus considered a more specific indicator of brain activity compared to oxygenated or deoxygenated hemoglobin concentrations.

Alternative definition: The enzyme cytochrome c oxidase (CCO) or Complex IV, classified as a translocase EC 7.1.1.9), is a large transmembrane protein complex composed of several metal prosthetic sites and 14 protein subunits. It is the last enzyme in the respiratory electron transport chain of cells, and it is located in the inner mitochondrial membrane. It receives an electron from each of four cytochrome c molecules and transfers them to one oxygen molecule and four protons, producing two molecules of water. The transfer of electrons within the mitochondrial electron transport chain complexes occurs via several proteins bound redox factors. CCO contains four redox centers: two hems (known collectively as aa3) and two copper sites. The electrons pass between these centers in a series of redox reactions. All these redox changes have associated optical transitions. In the NIR region, one of the copper sites, the Cu-Cu dimer copper A (CuA), dominates the absorption spectrum, with a strong peak in the oxidized form centered around 830 to 840 nm. The difference between these absorption spectra (oxidized-reduced CCO) can be used to monitor changes in the redox states of the mitochondrial proteins. Total CCO concentration does not change over a short-time period (in the order of hours); therefore, for analytical purposes, it is only necessary to use the difference spectrum between the oxidized and reduced species to obtain an indicator of the changes in the CCO redox state.

Synonym:

References: https://doi.org/10.1007/978-3-319-55231-6_19;

https://doi.org/10.1117/1.JBO.21.9.091307

Related terms: bNIRS

Oxygen

Definition: Oxygen is an element with atomic symbol O, atomic number 8, and atomic weight 16. It is necessary to fully metabolize glucose in order to prduce ATP as the energy source of cells (aerobic glucose metabolism).

Alternative definition:

Synonym: O2

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms: O2, Oxygenated Hemoglobin, Deoxygenated Hemoglobin

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Oxygen extraction fraction

Definition: The Oxygen extraction fraction (OEF) is the fraction of oxygen that is extracted from the blood by the brain tissue as it passes through the brain's circulatory system. OEF can thus be viewed as a proxy measure for efficiency of oxygen use for a respective tissue. In the context of neuroscience, OEF is a hemodynamic marker for brain ischemia and is thus relevant to brain diseases such as ischemic stroke.

Alternative definition:

Synonym:

References: https://doi.org/10.3389/fneur.2022.752450

Related terms:

Oxygenated Hemoglobin

Definition: Oxygenated hemoglobin is a complex molecule where the heme group of the hemoglobin protein has formed a reversible complex with oxygen (O$_2$) in the pulmonary capillaries. This red blood cell protein travels through circulating blood carrying oxygen to body tissues and organs where it is readily released.

Alternative definition:

Synonym: oxyhaemoglobin, oxy hemoglobin, oxyhemoglobin

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms: Hemoglobin, Deoxygenated Hemoglobin, Total Hemoglobin, Oxygen

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Physiological noise

Definition: In the context of fNIRS, physiological noise reflects physiological activity (e.g., blood pressure fluctuations related to heart rate, respiration, and low-frequency oscillations) that are not related to the hemodynamic signal of interest, i.e. the hemodynamic signal that indexes neural activity. Physiological noise can be captured as a global component in overall brain activity, or measured in surface vasculature, later to be removed from the fNIRS signal.

Alternative definition:

Synonym: Physiologic or Metabolic Artifact, Systemic Activity

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

https://doi.org/10.1016/j.neuroimage.2019.116472

Related terms: Preprocessing, Artifact Correction, contamination, Extracerebral components, artifact, noise, Mayer wave

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Physiological respiration

Definition: Physiological respiration refers to the biological processes that are necessary to provide an organism with vital oxygen. These processes can be divided in three phases: 1) The intake and transport of respiratory gasses via the act of breathing, which involves, respiratory (e.g. the diaphragm) and auxiliary (e.g. intercostal) muscles, sensory input systems, and coordination by the central nervous system, 2) The ventilation of the gas exchanging organs, i.e. the lungs and 3) Cellular respiration in mitochondria that provide Adenosine triphosphate (ATP) as the source of energy for use and storage at the cellular level. The oxygen needed for cellular respiration is obtained via inhalation, while carbon dioxide that is generated is removed from the body via exhalation. Carbon dioxide is formed intracellularly as a byproduct of metabolism, mainly by the Krebs cycle. Carbon dioxide is transported in the bloodstream to the lungs where it is ultimately removed from the body through exhalation. Carbon dioxide plays various roles in the human body including regulation of blood pH, respiratory drive, and affinity of hemoglobin for oxygen. Alveolar ventilation and cerebral blood flow are both predominantly regulated by arterial blood gases, especially arterial carbon dioxide partial pressure, and so are intricately entwined. Fluctuations in carbon dioxide levels are highly regulated and can cause disturbances in the human body if normal levels are not maintained.

Alternative definition:

Synonym:

References: https://doi.org/10.1007/s40122-020-00203-2

Related terms:

Point of care testing (POCT)

Definition: Point of care testing refers to tests in which samples/data are collected, rapidly analyzed, and results reported in close spatial proximity to a patient. This is in contrast to a sample being sent off for a laboratory based test or a situation in which the patient must be transported, e.g., to an imaging suite. For instance, pulse oximetry is a use case of POCT that is routinely used in clinical practice. For brain related POCT NIRS applications, brain tissue oximetry is used as POCT during anesthesia, in intensive care or after neurosurgical interventions.

Alternative definition:

Synonym:

References: https://doi.org/10.1136/bmj.322.7297.1285; https://doi.org/10.1053/j.jvca.2021.07.015

Related terms:

Prefrontal cortex

Definition: Defined anatomically, it is the frontal part of the frontal lobe and the region of the cerebral cortex that receives projections from the mediodorsal nucleus of the thalamus. Functionally, the prefrontal cortex is predominantly involved in executive functioning, problem-solving, action planning, and "top-down" cognitive control. Recruitment of the prefrontal cortex is necessary for many cognitive functions including (but not limited to) working memory, inhibition, decision-making, sustained attention, emotion regulation, and perspective-taking.

Alternative definition:

Synonym:

References: https://doi.org/10.1126/science.aan8868 https://doi.org/10.1016/B978-0-12-407815-4.00001-5 https://doi.org/10.3389/fneur.2018.00491 https://doi.org/10.1146/annurev.neuro.24.1.167 https://doi.org/10.1016/j.tins.2010.05.002

Related terms: frontal lobe; frontal cortex; executive functioning; cognitive control; dorsolateral prefrontal cortex; ventromedial prefrontal cortex; ventrolateral prefrontal cortex, medial prefrontal cortex, orbitofrontal cortex; Broca's area;

Primary motor cortex

Definition: It is a brain region that is located in the dorsal portion of the frontal lobe adjacent to the central sulcus. It has a strong somatotopic organization. It mediates voluntary movements of the limbs and trunk; it is called primary because it contains neurons that directly activate somatic motor neurons in the spinal cord. Complex sensory information is also sent to higher-order motor areas, located rostral to the primary motor cortex, where programs for movement, or potential movements, are calculated and conveyed to the primary motor cortex for implementation. Some of the motor areas in the frontal lobe also send commands directly to the spinal cord. Cells in the primary motor cortex influence neurons in the ventral horn of the spinal cord responsible for muscle movements, and thus the primary motor cortex is intimately associated with the motor system of the spinal cord.

Alternative definition:

Synonym: primary motor

References: E. Kandel. Principles of Neural Science, Fifth Edition. Principles of Neural Science. McGraw-Hill Education, 2013.

https://doi.org/10.1038/s41598-023-33780-1 https://doi.org/10.1016/j.jneumeth.2020.108790

Related terms: Brodmann area 4

Resting-State Networks

Definition: Resting state networks are a set of functional networks exhibited by the brain over its range of possible tasks, encompassing various spatially distinct neural systems, including the medial visual and lateral visual, auditory, somatosensory, motor, cerebellum, executive control, parietal memory, medial temporal lobe, salience,and frontoparietal or dorsal visual stream networks as well as the default mode network (DMN). These networks are constructed based on the signal fluctuations measured from the brain during rest and reflect the neuronal baseline of the brain, representing the state of the human brain in the absence of goal-directed neuronal action and external input.

Alternative definition:

Synonym: Reference(s): https://doi.org/10.1073/pnas.1007921107

References: E. Kandel. Principles of Neural Science, Fifth Edition. Principles of Neural Science. McGraw-Hill Education, 2013.

https://doi.org/10.1038/s41598-023-33780-1 https://doi.org/10.1016/j.jneumeth.2020.108790

Related terms: Resting-State Functional Connectivity (RSFC), Functional Connectome

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Scalp

Definition: The skin which covers the top of the head. Most of the scalp, except for the forehead, is usually covered by hair, which can affect optode-scalp coupling. Good coupling is fundamental to acquiring meaningful neuroimaging data with EEG and fNIRS.

Alternative definition:

Synonym:

References: National Cancer Institute. National Cancer Institute Thesaurus, 2017. Documentation page available on http://nciterms.nci.nih.gov.

Related terms: Skull, Hair, Skin, Dura

Scalp blood flow

Definition: Scalp blood flow (subcutaneous blood flow) refers to the blood circulating in the network of blood vessels within the scalp. It is influenced by various factors including cardiac output, ambient temperature and activity of the autonomic nervous system. Scalp blood flow changes can be measured by a laser Doppler flowmeter. Scalp perfusion can change during the measurement thus representing an extracerebral confounder in the fNIRS signal. Its interference can be minimized using short-separation channels sampling data from the scalp and regressing these out from the long-separation channels.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2016.08.058 https://doi.org/10.1117/1.NPh.2.2.025005

Seiyama A, Miura T, Sasaki Y, Okahashi S, Konishi N, Cassim M. Characterization of forehead blood flow bias on NIRS signals during neural activation with a verbal fluency task. Neurosci Res. 2023 Jan;186:43-50. doi: https://doi.org/10.1016/j.neures.2022.09.012

Related terms:

Scalp-cortex distance

Definition: The scalp-cortex distance refers to the distance between the cortex and the skin surface. The scalp-cortex distance on adults is about 15 mm. This distance can be influenced by various factors, including age, sex, and specific location on the scalp. For example, in children, this distance is typically smaller than in adults. Within an individual, the scalp-cortex distance may be greater in areas with larger volumes of cerebrospinal fluid or other intervening tissues.

Alternative definition:

Synonym:

References: https://doi.org/10.4103/joacp.JOACP_395_19

https://doi.org/10.1016/j.neuroimage.2003.08.026

Related terms:

Skull

Definition: The skull consists of flat or irregular bones that underlie the skin of the head. There are eight cranial bones that protect the brain and 14 facial bones. The bones of the skull develop separately but fuse together as they mature. Serrated joints/sutures are only present in the skull. Skull thickness varies with age, with adults displaying greater skull thickness compared to infants and young children.

Alternative definition:

Synonym: cranium

References: L. Shaw. Anatomy and Physiology. Access to HE. Nelson Thornes, 2005.

Related terms: Hair, Scalp, Skin, Dura

Structural Connectivity

Definition: Structural connectivity is the set of physical or structural (synaptic) connections linking neuronal units across the central nervous system. Structural connectivity data can range over multiple spatial scales, from local circuits to large-scale networks of inter-regional pathways.

Alternative definition:

Synonym: Anatomical Connectivity

References: https://doi.org/10.1016/j.tics.2004.07.008

Related terms: Functional Connectivity (FC), Effective Connectivity (EC), Dynamic Functional Connectivity (dFC), Background functional connectivity (bFC)

Sulcus

Definition: A groove, an inward fold in the surface of the cerebrum running between neighboring gyri.

Alternative definition:

Synonym:

References: M.F. Bear, B.W. Connors, and M.A. Paradiso. Neuroscience: Exploring the brain. Neuroscience: Exploring the Brain. Lippincott Williams & Wilkins, 2007.

Related terms: gyrus, fissure, sulci

Superficial tissue layer

Definition: Superficial tissue layer is a layer of tissue superficial with respect to the tissue of interest. For instance, the scalp and meninges are superficial to the brain. For non-invasive diffuse optical measurements, the static or dynamic optical and physiological properties of the superficial tissue can contaminate or degrade the accuracy and precision of measurements obtained from the deep tissue of interest.

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.2.3.035004

Related terms:

Systemic low frequency oscillations

Definition: Oscillations in fNIRS signals in the frequency range below the heart rate frequency (< $\sim$ 1 Hz). They can be spontaneous and induced by the experimental paradigm. Their sources are multifaceted and include changes in blood volume, hemoglobin oxygenation and the vasculature itself. Physiological processes underlying these effects are for example changes in blood pressure, concentration of CO2 in the blood and activity changes of the autonomic nervous system. A particular oscillation in this frequency range is the Mayer wave oscillation at about 0.1 Hz. SLFOs are always present in fNIRS and fMRI recordings and need to be properly addressed in data analysis. In addition, SLFOs can be also analyzed to gain valuable physiological information.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2003.11.025 https://doi.org/10.1016/j.neuroimage.2013.04.107
https://doi.org/10.1117/1.JBO.21.10.101410

https://doi.org/10.1038/srep17471

https://doi.org/10.1006/nimg.2000.0657

https://doi.org/10.3389/fnhum.2015.00285;

https://doi.org/10.3389/fnhum.2018.00505

https://doi.org/10.3389/fnins.2016.00313;

https://doi.org/10.3389/fnins.2019.00433;

https://doi.org/10.1177/0271678X17753329

Related terms: Physiological Noise, Systemic Activity, Preprocessing, Artifact Correction, Mayer wave, Blood pressure, Respiration

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Systemic Response

Definition: The systemic response describes the response associated with the body's functions, such as heart rate, digestion, respiratory rate, etc., which are controlled by the autonomic nervous system. These functions change the volume of blood in tissue and affect hemodynamics globally. As a result, the near-infrared spectroscopy technique is sensitive to the regular fluctuations induced by a systemic response, which should be considered when interpreting optical measurements. Even though some of these functions have distinct frequency signatures, their slow components can overlap with neural and scalp hemodynamics and local vessel dynamics (e.g., vasomotion).

Alternative definition:

Synonym:

References: https://doi.org/10.1117/1.NPh.9.3.030801

https://doi.org/10.3389/fnins.2022.803297

https://doi.org/10.1371/journal.pone.0050271

https://doi.org/10.1016/j.neuroimage.2013.05.004

https://doi.org/10.1117/1.nph.3.3.031405

Related terms:

Temporal lobe

Definition: The region of the cerebrum lying under the temporal bone. The temporal lobe is concerned with hearing and (through its deep structures, the hippocampus and amygdaloid nuclei) with learning, memory, and emotions. It also has a strong role in object / person identification and memory.

Alternative definition: the temporal lobe is a region of the brain that is located on the lower side of the cerebral cortex and is important for functions such as memory, language, perception, and emotion. It is bounded by the lateral sulcus on the lateral side and the parieto-occipital sulcus on the medial side, and includes several subregions, including the primary auditory cortex, the hippocampus, and the amygdala. The temporal lobe is involved in processing auditory information, forming and retrieving memories, processing emotions, and recognizing faces and objects.

Synonym: Frontal lobe, parietal lobe, occipital lobe

References: E. Kandel. Principles of Neural Science, Fifth Edition. Principles of Neural Science. McGraw-Hill Education, 2013.

Related terms:

Topography

Definition: The term topography refers to the mapping of the changes in brain hemodynamics associated with neuronal activity onto the brain cortex or a specific surface. Topographic maps represent two-dimensional images generated by measuring the changes in the brain optical properties at multiple measurement sites (or channels) that can be used to localize where brain activity occurs in the regions probed by the fNIRS array.

Alternative definition: The term topography can be understood in relation to two leading themes. The first concerns the topographical division of the brain. It is based on the developmental pattern of individual brain structures. For this reason, it is often called a developmental or ontogenetic division (from the Latin ontogenesis, which means personal development). In this division, the components of the brain are the primary brain follicles of the embryo. The advantages of this division are its precision and reference to the development of structures. Its disadvantages are the difficulty of remembering and discrepancy with the functional division. Sometimes structures belonging to two different secondary cerebral vesicles have similar functions. Another topic related to topology is the so-called topographic map of the brain, that is, the ordering of elements in the structure - in particular, the ordered spatial relationship between the distribution of nerve receptors in the corpus callosum area and the associated spread of neurons representing the same functions in the cortical areas of the brain. This is one of the key principles of brain organization, shaped throughout development. In theoretical models, spatial topography in connectivity is postulated to have the function of ensuring the fidelity of information transmission in the network. The topographical organization of connections also has the potential to generate complex abstract representations through topographical overlap.

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2012.03.049

Related terms: Multichannel, Tomography

Topology

Definition: Topology refers to the way in which the components of the nervous system are arranged or related to each other, and can be modified in disease or developmental disorders. It is closely related to the functional network of neuronal connections in the brain and can be described using graph theory. Topology can be used to estimate properties of the network, such as resistance to attack and distance between connected nodes, and is studied through various experimental methods including structural and functional MRI, DTI, MEG, and EEG.

Alternative definition:

Synonym:

References: https://doi.org/10.1007/s00429-021-02435-0

https://doi.org/10.1038/s41598-020-74392-3

https://10.3389/fpsyt.2018.00704

https://doi.org/10.1016/j.dcn.2013.11.004.

https://doi.org/10.1155/2020/8837615

https://doi.org/10.3389/fnins.2022.814477

https://doi.org/10.1111/jcpp.12365

Related terms:

Total hemoglobin

Definition: Total hemoglobin concentration ([tHb]) is defined as the sum of oxygenated and deoxygenated hemoglobin concentration [O2Hb] + [HHb]; sometimes referred as [HbT] or [HbTot]. [tHb] is measured only by frequency domain multidistance NIRS and Time-domain NIRS. Continuous wave instrumentations can measure total hemoglobin concentration changes (δ[tHb]) defined as the sum of oxygenated and deoxygenated hemoglobin concentration changes δ[O2Hb] + δ[HHb]; sometimes referred as δ[HbT] or δ[HbTot].

Alternative definition:

Synonym:

References:

https://doi.org/10.1139/h04-031

https://doi.org/10.1117/1.nph.3.3.031405

Related terms: Oxygenated Hemoglobin, Deoxygenated Hemoglobin, Total Hemoglobin

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Post-stimulus Undershoot

Definition: Post-stimulus undershoot refers to the transient drop of the oxygenated hemoglobin signal below baseline level after the stimulation ends. It is subject to a range of physiological factors and is likely mostly driven by an increase in the cerebral metabolic rate of oxygen (CMRO$_2$). Other physiological factors that partly also contribute include post-arterial cerebral blood volume (CBV$_{pa}$) and cerebral blood flow post-stimulus undershoot (CBF-PSU). These are more dependent on the interplay of brain region and stimulus length and type. A default form of post-stimulus undershoot is modeled in the canonical hemodynamic response function for BOLD analyses.

Alternative definition:

Synonym:

References: https://doi.org/10.1016/j.neuroimage.2005.09.048; https://doi.org/10.1016/j.mri.2005.12.034

https://doi.org/10.1016%2Fj.neuroimage.2012.01.029

Related terms: blood-oxygenation level-dependent (BOLD) post-stimulus undershoot, hemodynamic response, hemodynamic response function, cerebral metabolic rate of oxygen

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Vasodilation

Definition: Vasodilation is the dilatation/opening of the blood vessels, resulting in increased blood flow and/or reduced resistance to blood flow.

Alternative definition:

Synonym:

References: M.F. Bear, B.W. Connors, and M.A. Paradiso. Neuroscience: Exploring the brain. Neuroscience: Exploring the Brain. Lippincott Williams & Wilkins, 2007.

Related terms: vasoconstriction

Voxel

Definition: A voxel is a term for an element of a three-dimensional space that corresponds to a pixel for a given slice thickness. It represents a single sample or data point on a regularly spaced three-dimensional grid and does not represent a volume. The position of a voxel is determined by its position relative to other voxels, and rendering systems do not encode the position with the values. Voxels are useful for representing regularly sampled spaces that are non-uniformly filled, but cannot effectively represent simple 3D structures with empty or uniformly filled space. The missing information between voxels can be reconstructed or approximated through interpolation.

Alternative definition: Voxel is the 3D analog of pixels (the name is a contraction of volumetric pixel). Each voxel corresponds to a small cubic volume within space. At each voxel, a boolean is stored which indicates the presence or absence of the volume at that point.

Synonym:

References: M.F. Bear, B.W. Connors, and M.A. Paradiso. Neuroscience: Exploring the brain. Neuroscience: Exploring the Brain. Lippincott Williams & Wilkins, 2007.

Related terms: Volume, pixel

Absorption of Light

Definition: Absorption is the transformation of the photon energy from electromagnetic radiation (such as visible or near-infrared light) into another form of internal energy by an atom or a molecule. In an absorbing medium, absorption reduces the amount of light as the light passes through the medium.

Alternative definition:

Synonym:

References: https://doi.org/10.1036/1097-8542.001600

Related terms: Light Intensity

Absorption coefficient

Definition: The absorption coefficient of a medium, μ_a is related to the probability of a photon to be absorbed by the medium after it travels some distance in the medium; more precisely, it is the rate of photon absorption per unit length in the medium. The absorption coefficient depends on medium composition and light wavelength. The inverse of the absorption coefficient, known as the absorption length, l_a can be understood as the distance traveled by a photon before its probability of not being absorbed in the medium has decreased by e^{-1}. Quantitatively, the absorption coefficient can be related with the light intensity attenuation as it traverses the medium. Let I represent the intensity at any point of the path, such that the differential intensity is dI, dl a differential length along the path of the radiation. Then $\frac{dI}{dl}=-mu_al$, and the constant μ_{a} is known as the absorption coefficient.

Alternative definition: At any given point in the path of radiation, the Absorption Coefficient determines the fractional reduction in intensity per unit length of the path.

Synonym:

References: https://doi.org/10.1036/1097-8542.001600

Related terms: Absorption

Absorption spectrum

Definition: Absorption spectrum describes the fraction of incident radiation that is absorbed by the material as a function of the wavelength, frequency, or photon energy of the incident light. When photons impinge on a medium, their transmission depends on a combination of reflectance, scattering and absorption. Absorption occurs at specific wavelengths, determined by the atomic or molecular properties (energy states) of the materials in the light path.

Alternative definition:

Synonym:

References: https://doi.org/10.1017/CBO9781139029797

Related terms: Absorption, Absorption coefficient

Anisotropy factor

Definition: The anisotropy factor,g, is the average cosine of the scattering angle for a typical scattering event, i.e., $g=<\cos \theta>$. For example, if each scatter tends to scatter incident photons into the forward direction, then the anisotropy factor will be close to unity; if the scattering tends to be isotropic, then the factor will be close to zero. The anisotropy factor can also define single scattering events.

Alternative definition:

Synonym: Asymmetry factor

References: https://doi.org/10.1117/3.2624517

Related terms: Scattering phase function, Reduced scattering coefficient

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Arterial Oxygen Saturation

Definition: Fraction of functional hemoglobin in arterial blood that is saturated with oxygen. Oxygen saturation is normally expressed as a percentage (by multiplying the fraction by 100 %).

Alternative definition:

Synonym:

References: ISO 80601-2-85:2021, 201.3.219

Related terms:

Attenuation

Definition: Attenuation of light refers to the reduction in the intensity of light as it travels through a medium. This loss is due to a number of factors. The light:1 . spreads out and suffers an inverse square law type reduction in intensity with distance 2 .is scattered away from its original direction, or 3 . is absorbed in the medium. In fNIRS, attenuation A in the tissue is expressed as $A = A_{10} = -log_{10}\frac{I}{I_0}$ where I is the transmitted intensity and I_0 I0 the input light intensity. A_{10} A10 is sometimes termed optical density (OD). Depending on the context, attenuation can also be defined via the natural logarithm of the ratio of intensities: $A_e = -log_e (\frac{I}{I_0} = log_e 10 \cdot A_{10} = 2.303 \cdot A_{10}$ According to the modified Beer-Lambert Law, changes in attenuation are related to changes in the absorption coefficient μ_a μa of the tissue $\Delta A_e = \Delta \mu_a L$ $\Delta A_{10} = \frac{ \Delta \mu_a L}{log_e 10} = \frac{\Delta \mu_a L}{2.303}$ where L is the mean pathlength. On the other hand, the contributions of oxy- (HbO_2) and deoxyhemoglobin (Hb) to the (wavelength-dependent) attenuation change are $ \Delta A_{10}(\lambda) = \epsilon_{HbO_2}(\lambda)\Delta c_{HbO_2} \cdot L + \epsilon_{Hb}(\lambda) \Delta c_{Hb} \cdot L $ Based on measurements of ΔA at two or more wavelengths, the resultant system of equations can be solved for the concentration changes of oxy- and deoxyhemoglobin. Note that the oxy- and deoxyhemoglobin absorption spectra in literature are usually provided in terms of ϵ , the molar decadic absorption coefficient (unit: L mol^{-1} -1 cm^{-1} -1 or M^{-1}-1 cm^{-1}-1).

Alternative definition:

Synonym:

References:

J.A. Pope. Medical Physics: Imaging. Heinemann advanced science. Pearson Education, 1999.

https://archive.org/details/medicalphysicsim0000pope

http://doi.org/10.1088/0031-9155/33/12/008

https://doi.org/10.1351/goldbook.A00028

Related terms: Absorption, Scattering, Extinction, Optical Density, Modified Beer-Lambert Law

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Beer-Lambert Law

Definition: Beer-Lambert Law is the linear relationship between absorbance of electromagnetic radiation and the concentration of an absorber in the medium through which the radiation travels. The general Beer-Lambert Law would be: $ A = \epsilon_lambda \cdot c \cdot d $ where A is the measured absorbance (i.e. $ -log_{10}\frac{I}{I_0}$, I is the intensity of the measured light and I_0 is the intensity of the incident light), ϵ_{λ} is the wavelength-dependent molar (decadic) absorption coefficient (formerly molar decadic extinction coefficient) with units of $M^{-1}cm^{-1}$, c is the concentration of the absorber (M^{-1}) and d is the pathlength of light (cm). Please note that the subscript λ is often dropped with the understanding that the value for ϵ is for a specific wavelength.

Alternative definition:

Synonym: Beer-Lambert-Bouguer Law

References:

https://doi.org/10.1002/cphc.202000464

https://doi.org/10.1017/CBO9781139029797

Related terms: modified Beer Lambert law, optical density, molar absorption coefficient

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Coherent Hemodynamics Spectroscopy

Definition: Coherent Hemodynamics Spectroscopy (CHS) is a method for collecting physiological information from the local cerebral response to systemic blood pressure changes or functional activation. CHS is based on the analysis of cerebral hemodynamic oscillations that are either induced or occur spontaneously at multiple frequencies, and that are measured with NIRS. Data are analyzed using a hemodynamic model, which enables extraction of physiological information, including blood transit times in the microvasculature and the autoregulation cutoff frequency. CHS is particularly promising for clinical applications in populations that show impairment in these functions, e.g. diabetes, Parkinson's disease, and stroke.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.03.037

https://doi.org/10.1016/j.neuroimage.2013.03.065 https://doi.org/10.1364%2FBOE.5.003403

Related terms:

Concentration

Definition: Concentration is the amount of a pure substance (solute) of interest within the amount of the whole substance (solution), and can be quantified as:$ C = \frac{Amount of solute}{Amount of solution}$ Concentration can be expressed in several ways. For example, molarity is a way of expressing concentration relating the number of particles of solute (expressed in moles) and the volume of the solution (expressed in liters). The unit of molarity is $moles/liter$, sometimes denoted by molar or M. Within fNIRS it is common to see changes in concentration expressed in square brackets, such as [HbO_2]. Others include mass, number or volume concentration referring to the relation of the mass, the number of entities or the volume of the solute and the volume of the solution.

Alternative definition:

Synonym:

References:

https://goldbook.iupac.org/terms/view/A00295

https://doi.org/10.1351/goldbook.A00295

Related terms:

Cross-talk

Definition: By cross-talk we mean to describe the phenomena that a genuine change in one chromophore concentration is also inducing a spurious measured concentration change in another. This phenomena can also apply to cross-talk between changes in the absorption and scattering coefficient. In the context of the hardware, cross-talk can also be applied in the context of physical measurement of light, where a direct measurement between a single source and detector can be contaminated by other sources of light. This is usually mitigated by the use of time multiplexing or frequency multiplexing. When utilizing silicon photomultipliers for

photodetection, optical cross-talk may occur when an incident photon hits a microcell. This initial discharge can cause additional discharges in adjacent microcells, leading to an undesired amplification of the signal output.

Alternative definition:

Synonym: Signal crosstalk

References:

https://doi.org/10.1016/j.neuroimage.2004.02.023

https://doi.org/10.1117/1.nph.3.3.031405

Related terms:

Depth sensitivity

Definition: In the context of fNIRS, which typically uses an array of measurement optodes on the scalp to measure the brain activity, depth sensitivity refers to its ability to detect localized changes in deep tissue optical properties. 'Depth' is typically measured normal to the surface of the skin. Sensitivity to depth depends on multiple factors in the instrumentation (e.g., illumination strength, detector efficiency, source-detector separation, data type), and tissue optical properties (e.g. chromophore concentration). It is crucial to note here that there is no singular depth being probed by fNIRS but rather it has a continuous distribution over the probed tissue volume which can change with time and with optical properties. Typically the longer the distance between the source and detector across the surface of the measurement body (scalp, phantom etc.), the deeper the depth sensitivity.

Alternative definition:

Synonym:

References: https://doi.org/10.1088/0034-4885/73/7/076701

https://doi.org/10.1364/ao.36.000075

https://doi.org/10.1117/1.JBO.26.5.056003

Related terms:

Differential path length factor

Definition: The differential path length factor (DPF) is a unitless factor that accounts for the differential pathlength of photon travel in human tissue. The DPF is calculated by dividing the mean optical pathlength by the distance between the emitter and detector. The DPF depends on age, gender, and wavelength.

Alternative definition:

Synonym:

References:

https://doi: 10.3389/fninf.2018.00037

https://doi.org/10.1016/j.neuroimage.2013.05.004

https://doi.org/10.1088/0031-9155/33/12/008

Related terms: Source-detector separation distance, Modified Beer Lambert law, Differential path length, Partial pathlength factor.

Diffraction

Definition: A behavior characteristic of all waves; the phenomenon wherein waves change their direction/bend around sharp corners,

or spread out after traveling through narrow apertures. The aperture width must be on the same order of magnitude of the wavelength for diffraction to occur. Diffraction is used in optical spectrometers to separate light into its component wavelengths and to measure the associated light for each wavelength.

Alternative definition:

Synonym:

References:

https://doi.org/10.1007/978-3-030-44146-3_7

Related terms:

Diffusion Approximation

Definition: A set of simplifying physical assumptions that enable one to derive the Diffusion Equation from the Radiative Transport Equation. The diffusion approximation makes several assumptions about photon transport in tissue: (1) the scattering coefficient is much higher than the absorption coefficient; (2) the fluence rate is significantly larger than the photon flux; (3) the light source is isotropic; (4) the scattering angle of a scattering event in tissue does not depend on the incident angle, and; (5) the rate of change of the photon flux is very slow, which requires that the time scale of source modulation is much longer than the time between photon scattering events. As a result of the diffusion approximation, the modeling of light transport in highly scattering media is drastically simplified, which allows the derivation of analytical solutions to the problem and, therefore, a valuable and powerful tool for analyzing light distribution in tissues. Most tissues satisfy these assumptions, although even in these cases some of the assumptions may fail either too close to boundaries or too near sources.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/3.2624517

https://doi.org/10.1088/0266-5611/25/12/123010

https://doi.org/10.3254/978-1-60750-755-0-51

https://doi.org/10.1088/0266-5611/15/2/022

Alternative definition:

Related terms: Diffusion Equation, Radiative Transport Equation, photon fluence, photon flux

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Diffuse Correlation Spectroscopy

Definition: Diffuse Correlation Spectroscopy (DCS) uses the temporal fluctuations of speckles formed on the tissue surface by coherent light to derive metrics for the motion of scatterers in highly scattering media such as blood cells flowing in tissue vasculature. The DCS technique was formulated based on the correlation diffusion equation; it is formally equivalent to the technique (formulated as an integral equation rather than a differential equation) called diffuse wave spectroscopy (DWS). In the diffuse optics community the term DWS sometimes implied absorption spectroscopy, hence the term DCS was introduced to reduce terminology confusion. The word "correlation" in the name is connected with the fact that canonical DCS uses the auto-correlation function of the intensity fluctuations as its primary measured quantity. Apart from the usual optical properties (absorption and reduced scattering coefficients), the DCS signal (decay of the measured curve) in tissue is dominated by the movement of red blood cells which permits DCS to estimate a blood flow index. Standard DCS measures the autocorrelation function and fits these measurements to solutions of the correlation diffusion equation for the appropriate geometry and boundary conditions. DCS is closely related to the other speckle correlation techniques such as interferometric DCS and DWS (iDCS/iDWS), Speckle Contrast Optical Spectroscopy and Tomography (SCOS/SCOT), Laser Speckle Contrast Imaging (LSCI), and Diffuse Correlation Tomography (DCT). Other implementations of DCS have been described in the literature.

Alternative definition: Diffuse Correlation Spectroscopy (DCS) uses the fluctuation statistics of diffuse, coherent light to measure microvascular blood flow in tissues.

Synonym: Diffuse Wave Spectroscopy (DWS)

References:

https://doi.org/10.1103/PhysRevLett.75.1855

https://doi.org/10.1364/JOSAA.14.000192

https://doi.org/10.1016/j.neuroimage.2013.06.017

https://doi.org/10.1117/1.NPh.10.1.013509

https://doi.org/10.1098/rsta.2011.0232

Related terms:

Diffuse Optical Imaging

Definition: Diffuse Optical Imaging (DOI) measures multiple scattered light and inverts this data to spatially resolve optical properties of a diffuse medium, generally by utilizing a reconstruction algorithm. Optical properties, in turn, are used to compute physiological parameters (e.g., hemoglobin concentration). Diffuse optical imaging covers both Diffuse Optical Topography (reconstruction in 2D), and Diffuse Optical Tomography (reconstruction in 3D).

Alternative definition: Diffuse Correlation Spectroscopy (DCS) uses the fluctuation statistics of diffuse, coherent light to measure microvascular blood flow in tissues.

Synonym:

References:

https://doi.org/10.1088/0031-9155/50/4/r01

https://doi.org/10.1364/boe.467614

Related terms: Diffuse Optical Tomography, Optical Tomography, High Density Diffuse Optical Tomography, Functional Near Infrared Spectroscopy

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Dynamic range

Definition: The dynamic range of a given quantity is the ratio between the largest and the smallest value it can assume. In the context of NIRS devices, it often describes the range of the device operation (i.e., the range between the saturation level and the noise level). It is often further limited to the linear range between these two extremes.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.2363365

Related terms: Saturation

Electrical Field Temporal Autocorrelation Function

Definition: The unnormalized Electric Field Temporal Autocorrelation function (G_1) is the temporal autocorrelation function of the electric field traversing the scattering medium or (more typically) emitted/scattered from the medium. It is a key function used in the analysis of data from measurements implementing diffuse correlation spectroscopy (DCS) and related methods that utilize laser speckle statistics. G_1 is modeled by the correlation diffusion equation and its normalized form, g_1, is used to fit the measured data.It can be written as $G_1(\bf{r}, \tau,t) = < E (\bf{r},t) E^* (\bf{r},\tau+t)>$. In a typical experiment, it is derived from the

normalized intensity autocorrelation function (g_2) that is often the main measured quantity in DCS by relying on the so-called "Siegert relation". The Siegert relationship between intensity based autocorrelation function (g_2) and electric field temporal autocorrelation (g_1) is $g_2 (\tau) = 1 + \beta |g_1(\tau)| 2$

Alternative definition:

Synonym: Normalized Electric Field Temporal Autocorrelation (g1)

References:

https://doi.org/10.1364/JOSAA.14.000192

https://doi.org/10.1103/PhysRevLett.75.1855

https://doi.org/10.1016/j.neuroimage.2013.06.017

https://doi.org/10.1088/0034-4885/73/7/076701

Related terms: Intensity Temporal Autocorrelation (G2), Diffuse Correlation Spectroscopy

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Event-related optical signal

Definition: Event-related optical signals (EROS) arise from the changes in optical scattering that occur when the neurons become hyperpolarized or depolarised during brain activity. They can be measured from the scalp using NIRS and they are more closely related to neuronal activity than the hemodynamic responses. In fact, the localized brain response is within milliseconds in terms of temporal resolution and in the sub-centimetre range for spatial resolution. The NIRS device must have a sampling rate of at least 100 Hz sampling rate and/or be capable of quantifying scattering changes. Typically these measurements have been difficult to reproduce and are not widely used.

Alternative definition:

Synonym:

References:

https://doi.org/10.3758/BF03208834

https://doi.org/10.3389/fnhum.2010.00052

Related terms: infrared light scattering, Fast Optical Signal

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Fast Optical Signal

Definition: Fast optical signal (FOS) (also known as Event-related optical signal (EROS) for the time-locked to particular events) is the signal measured on a time scale ~100ms and it is thought to be related to scattering changes due to neuronal activity: when neurons pass from an inactive state to a hyperpolarized or depolarised state, they cause a change in the scattering of the tissue. FOS are more closely related to neuronal activity than the hemodynamic response.

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fnhum.2010.00052

https://doi.org/10.1016/j.neuroimage.2005.03.006

https://doi.org/10.1162/jocn.1995.7.4.446

https://doi.org/10.1016/j.neuroimage.2010.02.076

Related terms: EROS (Event-related Optical Signal)

Fluence

Definition: The fluence represents the (optical) energy delivered per unit area over a time interval from all directions about a given point within a turbid medium. The fluence is proportional to the number of photons in the unit volume regardless of their direction of motion.

Alternative definition:

Synonym:

References:

https://doi.org/10.1017/CBO9781139029797

https://doi.org/10.1002/cnm.1162

https://doi.org/10.1117/3.2624517

Related terms: Light intensity

Frequency

Definition: The frequency of a periodic event is the number of repetitions per second. Frequency is measured in Hertz (Hz), a frequency of n Hz indicates that a periodic cycle has repeated itself n times per second.

Alternative definition:

Synonym:

References:

https://doi.org/10.1017/CBO9781139029797

Related terms:

Frequency Range

Definition: Frequency range refers to an interval defined by lower and upper frequency values. A system, whether biological or electronic, either produces or responds to signals, which generally consist of a great number of components with different frequencies. Therefore, the term also refers to the set of signals that are significant for a system or that a system can detect and generate a non-negligible, consistent response against (e.g., human ear can detect sounds within a window of 20 Hz - 20 kHz) or that can be consistently produced by a system (e.g., oscillators). fNIRS can measure several frequency ranges of physiological interest, such as heart rate, respiration, low-frequency oscillations (typically associated with functional connectivity), and the hemodynamic response related with the neural activity.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Frequency

Illumination

Definition: The term illumination refers to the act of applying light (near-infrared light, 650–950 nm) over an area of interest (such as the individual's head) using light sources directly or through wave guides (optical fibers). The source of illumination can be a thermal lamp, a light amplification by stimulated emission of radiation (LASER), or a light-emitting diode (LED).

Alternative definition:

Synonym:

References:

https://doi.org/10.3389/fnhum.2014.00549

https://doi.org/10.1017/CBO9781139029797

Related terms: Infrared light, Source, Emitter

Intensity Temporal Autocorrelation (G2)

Definition: Intensity Temporal Autocorrelation (G_2) or its normalized form, "Normalized Intensity Temporal Autocorrelation (g_2)", is the most commonly measured quantity in Diffuse Correlation Spectroscopy (DCS) measurements. Normalized Electric Field Autocorrelation function is often derived from g_2 using the so-called "Siegert Relation" which is used to fit DCS data. In Siegert relation, the relationship between $g_2(\tau)$ and $g_1(\tau)$ is; $ g_2(\tau) = 1 + \beta |g_1 (\tau) |^2 $. In this equation, β is an experimental factor which is equal to 1 for an ideal experimental design.Its formal definition is $G_2 ({\bf{r},\tau,t) = $ where $\bf{r}$ is the source-detector separation/position, τ is the delay time in the autocorrelation, t is time and $<...>$ indicate ensemble averages.

Alternative definition:

Synonym: Normalized Intensity Temporal Autocorrelation (g2)

References:

https://doi.org/10.1364/JOSAA.14.000192

https://doi.org/10.1103/PhysRevLett.75.1855

https://doi.org/10.1016/j.neuroimage.2013.06.017

https://doi.org/10.1088/0034-4885/73/7/076701

Related terms: Electric Field Temporal Autocorrelation Function, Diffuse Correlation Spectroscopy

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Interferometric near-infrared spectroscopy (iNIRS)

Definition: A time-of-flight (TOF) resolved sensing technique used to identify the optical and dynamical characteristics of a turbid medium. This is measured by the interference pattern from the spectrum of light traversing the medium with a rapidly tunable or frequency-swept light source. The performance of the iNIRS system depends on the spectral and tuning parameters of the light source, with the spectral linewidth determining the TOF range, while the bandwidth determines the TOF resolution.

Alternative definition:

Synonym:

References:

https://doi.org/10.1364/OE.24.000329

Related terms:

Isosbestic point

Definition: An isosbestic point is the wavelength in which two or more chromophores have the same absorption coefficient. The isosbestic point of interest in NIRS is for oxygenated and deoxygenated hemoglobin, and is at ~800 nm.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.05.004

Related terms: Oxygenated Hemoglobin, Absorption Spectrum, Absorption Coefficient

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Laser

Definition: Laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term laser originated as an acronym for light amplification by stimulated emission of radiation. As a consequence, the laser produces light within a narrow band of the electromagnetic spectrum (monochromatic). The laser light is also coherent (the light waves are in phase) and highly collimated (all rays are parallel to each other and do not diverge significantly).

Alternative definition:

Synonym:

References:

https://doi.org/10.1364/ao.49.000f99

Related terms: Light Source, Emitter, Optode

Light

Definition: Light is a form of radiant energy emitted from a luminous body. It is a general term referring to electromagnetic radiation in the visible part of the spectrum for humans, ranging approximately from 650 to 900 nm (1 nm = 10^{-9} m). Its electromagnetic waves travel in free space with the speed of 3×10^{8} m/s. Like all electromagnetic radiation, light can also be interpreted not only as waves but also as discrete "packets" of energy (quanta) known as photons.

Alternative definition:

Synonym:

References:

https://doi.org/10.1364/ao.49.000f99

Related terms:

Light Intensity

Definition: Light intensity is the radiant power received by a surface per unit area, due to illumination, or the radiant power received per unit solid angle. Radiant power is the energy received per unit time. SI units for light intensity are watt per meter squared (W/m^2) or watt per steradian (W/sr).

Alternative definition:

Synonym: Radiant Intensity, Optical Intensity, Irradiance, Illuminance

References:

https://doi.org/10.1142/7609

Related terms:

Light source

Definition: A light source is any body that emits light. The bodies which have their own power of radiating light are known as self-luminous. The bodies which have no light of their own but are visible only by the light falling on them from other sources are said to be non-luminous bodies. The light sources which can be approximated as geometrical points are called points sources. Light sources that extend over one dimension or more are termed extended sources; such sources consist of innumerable point sources. In the context of fNIRS, a light source refers to a device (e.g., laser, LED, lamp) emitting light onto the surface of the tissue or phantom of interest.

Alternative definition:

Synonym: source

References:

https://doi.org/10.1117/1.NPh.8.1.012101

Related terms: Laser

Molar absorption coefficient

Definition: The molar (decadic) absorption coefficient (formerly: molar decadic extinction coefficient) is an intrinsic property of a given molecule (chromophore) or substance that describes how strongly that molecule/substance absorbs light at a particular wavelength. It is equal to absorbance (A, base 10) divided by the absorption pathlength, d, and the amount concentration, c: $ \epsilon(\lambda) = -\frac{1}{cd}log_{10}(\frac{I_d}{I_0}) = \frac{A(\lambda)}{cd} $ It is generally represented by the unit M^{-1} cm$^{-1} (= $L mol^{-1} cm^{-1}.

Alternative definition:

Synonym: molar absorption coefficient, molar attenuation coefficient

References:

https://doi.org/10.1351/goldbook

https://doi.org/10.1351/goldbook.M03972

Related terms: optical density, modified beer-lambert law, attenuation, absorption of light

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Near infrared spectroscopy

Definition: Near-infrared spectroscopy (NIRS) is an analytical optical technique that uses near-infrared light (650 - 900 nm) to shine light to a sample and measures the portion of the light that travels through the sample. NIRS has been used in many fields such as agriculture, food, chemical industries, clinical chemistry, pharmaceutical, and medicine. Absorption and/or fluorescence NIRS is utilized in different techniques with different resolution and penetration depth, such as conventional microscopy, confocal/multi-photon microscopy, optical coherence tomography, photodynamic therapy, in vivo molecular imaging and medical diffuse optical imaging. The main applications in medicine are pulse oximetry, brain/muscle oximetry, functional NIRS and optical mammography.fNIRS typically uses the NIR range between 650–900 nm at which the light can travel a couple of centimeters deep in tissue. This is due to the fact that the absorption of light by the main chromophores in tissue (i.e hemoglobin, water, lipids, collagen, melanin and proteins) is relatively small in this “optical window”. fNIRS devices typically contain a set of light sources that emit NIR light in the optical window at two or more wavelengths and a set of detectors to collect light back from the sample. The detected light is then used to estimate the absolute values or relative changes in chromophore concentrations using the modified Beer-Lambert Law, generally in a context where these changes reflect functional brain activity Frans Jöbsis is considered the founder of in vivo medical NIRS that enables real-time non-invasive detection of regional hemoglobin oxygenation.

Alternative definition:

Synonym:

References: DOI:

https://doi.org/10.1126/science.929199

https://doi.org/10.1016/s0166-2236(97)01132-6

https://doi.org/10.1255/jnirs.973

https://doi.org/10.1117/1.JBO.20.3.030901

https://doi.org/10.1016/j.neuroimage.2013.05.004

Related terms: functional Near Infrared Spectroscopy

Nyquist Frequency

Definition: For signal processing systems that transform a continuous-time signal to a discrete-time signal, the Nyquist Frequency is the maximum frequency that can be acquired at a given sampling rate in order to be able to reconstruct the signal completely afterwards. Typically it is 0.5x the sampling rate of your system. Beyond the Nyquist frequency, the signal experiences a distortion known as 'Aliasing'.

Alternative definition:

Synonym: Folding frequency, Nyquist Limit

References:

https://mathworld.wolfram.com/NyquistFrequency.html

https://doi.org/10.1109/PROC.1967.5962

Related terms:

Optical density

Definition: Optical density (or Absorbance) is defined as the (decadic) logarithm of the ratio of incident to transmitted radiant power through a (non-scattering) sample. This quantity is used, e.g., in spectrophotometry to characterize a dissolved chromophore in a non-scattering solution or an optical filter. Absorbance is defined as: $A = -log_{10} T = -log_{10}(\frac{I_d}{I_0}) where A is the absorbance or optical density, T is the transmittance, I_{d} is the intensity of the transmitted light after the light traveling a pathlength d, and I_{0} is the intensity of the incident light. For a single chromophore, T can be written as $T = e^{-\mu_a d} = 10^{-\epsilon cd}$ where a μ_a is the absorption coefficient, ϵ is the molar decadic absorption coefficient, c is the concentration of the chromophore. This equation leads to $A = \epsilon cd = \frac{\mu_a d}{log_e 10}$ $\mu_a = log_e 10 \cdot \epsilon c = 2.303 \epsilon c$ In fNIRS, optical density (OD) is sometimes used as a synonym for (decadic) attenuation (termed A as well). In this context, attenuation is relevant instead of absorbance since it also includes the effect of light scattering.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117%2F1.NPh.8.1.012101

Related terms:

Optical Pathlength

Definition: In broader context, the term refers to the trajectory that the light follows within a medium. Path length is the distance obtained as the product of the propagation velocity and the propagation delay between two points. In the propagation of waves, path length is the length that is proportional to the time a wave or signal takes to travel from one point to another. Within the fNIRS (or optical imaging) framework, it refers to the trajectory that the emitted light follows from source to the detector within the tissue (e.g., scalp, brain, etc.). In tissue or brain imaging scattering is dominant and leads to many different trajectories. The path of light when measured from a source to a detector exhibits a banana-shaped curve and it is directly proportional to the physical length between the source and detector.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117%2F1.NPh.8.1.012101

Related terms: Differential Path length factor, Photon Banana

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Optical tomography

Definition: Optical tomography describes techniques which generate full three-dimensional (3D) images from measurements taken from sources and detectors covering a substantial part of the surface of the object. Data is obtained from light that has traveled across the object under examination. The image reconstruction in optical tomography can be approximately divided into two kinds: the first is a linearization approach and another is a nonlinear iterative approach. The former reconstructs images of measured changes, while the latter enables quantitative image reconstruction of an object. Nonlinear image reconstruction methods are used due to the use of the diffusion approximation, and typically these generate images that can be shown on a three dimensional tissue volume. It is also possible to attempt to separate the effects of absorption and scatter, which requires measurements of both the intensity and the mean flight time (or, equivalently, phase) of the transmitted light because (in the absence of prior information) measurements of intensity only are unable to distinguish between absorption and scatter at a single wavelength. There are several different techniques for performing tomography in NIRS, including diffuse optical tomography (DOT) and functional diffuse optical tomography (fDOT). These techniques use sophisticated algorithms and mathematical models to reconstruct the distribution of changes in hemoglobin concentration within the tissue of interest, e.g the brain, or breast.

Alternative definition: Tomography is a general term for the reconstruction of the image of sections of a volume using energy which penetrates the volume. In the context of optical near-infrared spectroscopy, tomography refers to the reconstruction of the optical or physiological properties of a volume with illumination and detection on the surface or embedded in the volume. There are several different techniques for performing tomography in NIRS, including diffuse optical tomography (DOT) and functional diffuse optical tomography (fDOT). These techniques use sophisticated algorithms and mathematical models to reconstruct the distribution of changes in hemoglobin concentration within the tissue of interest, e.g brain, breast etc.

Synonym:

References:

https://doi.org/10.1016/B978-0-12-386456-7.07605-X

https://doi.org/10.1063/1.5086809

Related terms: Diffuse optical tomography

Optical topography

Definition: Methods which produce two-dimensional (2D) images of a plane parallel to the sources and detectors with limited depth information. It refers to imaging a few centimeters of tissue (the separation between source and detector is generally < 4 cm). The typical application is imaging haemodynamic changes in the cortex of the brain, where we are interested in imaging a change in optical properties with a time course of a few seconds. Such systems generally employ continuous-wave instrumentation with laser diode sources modulated at a few kilohertz and lock-in detectors. Images are usually reconstructed using a linear approach and presented as a two-dimensional slice parallel to the plane of sources and detectors.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/B978-0-12-386456-7.07605-X

Related terms: Functional Near Infrared Spectroscopy, Diffuse Optical Tomography

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Optical window

Definition: The optical window for biological tissues defines a range of wavelengths (650-900 nm) where light can penetrate through tissues such as skin and bone more efficiently than visible light because these tissues scatter and absorb less light at these wavelengths, rendering them nearly transparent. fNIRS takes advantage of this window, where water absorption is low and oxygenated and deoxygenated hemoglobin are strong absorbers of light at these wavelengths, with contrasting levels of absorption coefficient in this range.

Alternative definition:

Synonym: near-infrared window; therapeutic window

References:

https://doi.org/10.1038/nnano.2009.326

https://doi.org/10.1038/s41377-021-00628-0

Related terms: oxygenated hemoglobin, deoxygenated hemoglobin, absorption spectrum, absorption coefficient

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Optode-scalp coupling

Definition: Optode-scalp coupling refers to how well an optode is connected to the scalp. Effective optode-scalp coupling ensures the transmission of light from the emitter to the tissue and detection from tissue to the detector. Often it is hair that obstructs the delivery and collection of light at the optode.

Alternative definition:

Synonym: Source-detector coupling

References:

https://doi.org/10.1364%2FBOE.7.005104

Related terms:

Partial pathlength

Definition: The path light travels within the fraction of tissue that is of interest, e.g., for functional brain activity, i.e. as opposed to the entire path between the source and detector. For example, the pathlength of the light is different in the scalp layer when compared to the CSF layer. Estimates of partial pathlengths are often obtained from Monte Carlo simulations, which numerically simulate the path taken by individual photons in tissue. It is the path only in the activated region in the inter-optode distance, multiplied by partial pathlength factor (PPF), which is the scaling factor that relates inter-optode distance to the average pathlength light travels within the activated region.

Alternative definition:

Synonym:

References:

https://doi.org/10.1364%2FBOE.7.005104

Related terms:

Path length factor

Definition: In functional near-infrared spectroscopy (fNIRS), the path length factor (PLF) is a correction factor that is used to account for the length of the optical path through the tissue being measured. This scaling factor is applied to the measured changes in optical density to account for the fact that light travels a longer distance or follows a banana shaped path rather than a straight way through the tissue when the source and detector are further apart. The PLF is typically calculated using a Monte Carlo simulation, which models the propagation of light through the tissue and calculates the average path length of the photons. The PLF is an important correction factor in fNIRS because it affects the accuracy of the measurements of changes in hemoglobin concentration. Without the PLF correction, the changes in optical density would be underestimated when the source and detector are further apart, leading to inaccurate estimates of the underlying neural activity.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.05.004

Related terms: Differential path length factor

Partial volume effect

Definition: The partial volume effect can be defined as the loss of contrast in small objects or regions due to the limited resolution of the imaging system. Thus, it refers to the underestimation of the concentration changes of hemoglobin due to the fact that they occur in small focal regions rather than in the entire sampling region.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.nph.8.1.012101

Related terms: Partial volume error

Partial volume error

Definition: It is the error that occurs when the partial pathlength and partial volume effects are not considered.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.nph.8.1.012101

Related terms: Partial volume effect

Penetration depth

Definition: The depth to which light can penetrate tissue to the extent of several centimeters is known as penetration depth. It is influenced by light scattering, absorption, the subject's anatomy, scalp-optode coupling, and the spacing between the light source and the detector. This is on the order of a few mm’s up to 15-20 mm.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/1.nph.2.2.025005

https://doi.org/10.1117/1.nph.6.3.035007

https://doi.org/10.1111/nyas.13948

https://doi.org/10.1177/1094428116658959

https://doi.org/10.1371/journal.pone.0026377

Related terms: Source Detector Separation, Absorption, Scattering, Photon Banana

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Photon

Definition: An elementary particle that is a quantum (unit) of electromagnetic radiation, such as visible light, often characterized by its frequency or wavelength. They are massless, exhibit wave-particle duality, and travel at $\sim 3x10^8 m/s$ (c) in a vacuum.

Alternative definition:

Synonym:

References:

https://doi.org/10.1006/rwsp.2000.0055

Related terms: Light, Wavelength, Frequency

Photon Banana

Definition: The term photon banana refers to the fact that the movement that measured photons will take between a source and detector in a biological tissue in light diffusion simulations appears like a banana shape.

Alternative definition:

Synonym:

References:

https://doi.org/10.1017/CBO9781139029797

https://doi.org/10.1109/MEMB.2006.1657788

https://doi.org/10.1117/1.nph.6.3.035007

Related terms: Photon Measurement Density Function (PDMF)

Photon Measurement Density Function (PMDF)

Definition: The Photon Measurement Density Function (PMDF) is a mathematical function that describes the probability distribution of photons reaching a particular detector or measurement point in a medium. It is obtained from the Green's function of the diffusion equation. The Green's function represents the response of the medium to a point source of light and can be used to calculate the photon density at any point in the medium. By integrating the photon density over the volume of the detector or measurement point, the PMDF can be obtained. The idea of a PMDF is an extension of the notions of a photon-sampling volume and a photon-hitting density. The mathematical formula for the photon-measurement density function (PMDF) depends on the specific

measurement type and the properties of the medium being studied. However, in general, the PMDF can be expressed as: $PMDF(x,t) = \int V G(x, x', t) \rho(x', t) dV$ where $PMDF(x, t)$ is the photon-measurement density function at a point x and time t, $G(x, x', t)$ is the Green's function of the diffusion equation, which describes the probability distribution of photons reaching point x at time t that originated at point x' at time t=0, $\rho(x', t)$ is the photon density at point x' and time t, and the integral is taken over the volume V of the detector or measurement point.

Alternative definition:

Synonym:

References:

https://doi.org/10.1364/AO.34.007395

Related terms: Photon Transport

Photon transport

Definition: Photon transport refers to the movement of a photon through tissue. In the case of fNIRS, it estimates photon movement as they pass from the source through the different tissues in the head model, with the goal of ending up with a sensitivity profile that can be used to create 3D voxel-based image reconstruction of the fNIRS data. For these applications, photon transport is often solved with Monte Carlo methods. The photon packet is launched, the step size is probabilistically selected, and as it passes through the medium, it loses weight due to absorption in the tissue, repeating these steps until a condition is met (detection, exit, …). Thus, scattering and absorption properties of the tissue is required to estimate photon transport.

Alternative definition:

Synonym: Photon migration

References:

https://doi.org/10.1016/0169-2607(95)01640-F

https://doi.org/10.1117/1.NPh.7.1.015008

Related terms: Photon transport modeling

Photon transport modeling

Definition: Photon transport modeling refers to the modeling or simulation of movement of a photon through tissue. In the case of fNIRS, we are modeling the propagation of photons as they pass from the source through the different tissues in the head model to the detector which can be used to created a sensitivity profile (jacobian) that can be used to create 3D voxel-based image reconstruction of the fNIRS data. For these applications, photon transport modeling is often performed with Monte Carlo methods, which can be performed quicker using graphics processing unit (GPU) technologies. In a photon transport model, a large number of photon packets are launched, the step size is selected, and as it passes through the medium undergoing multiple scattering events. The packets lose weight due to absorption in the tissue. Thus, scattering and absorption properties of the tissue are required to estimate photon transport, as well as the wavelength of the fNIRS device.

Alternative definition:

Synonym: photon migration simulation

References:

https://doi.org/10.1016/0169-2607(95)01640-F

https://doi.org/10.1117/1.NPh.7.1.015008

Related terms: Photon transport

Reduced scattering coefficient

Definition: The reduced scattering coefficient measures how much light is scattered by tissue assuming equal probability for the scattering angle (isotropic scattering) without absorption. Besides the absorption coefficient, it is one of the two main optical parameters that model light propagation through tissue in the diffusion approximation. Reduced scattering coefficient can be formulated as:${\mu}_s^{\prime}={\mu}_s(1-g)$ with μ_s as the scattering coefficient, a measure of how much light is scattered per unit distance when considering single scattering; and $ g = $ as the anisotropy factor, describing the degree of forward versus backward scattering of light.

Alternative definition:

Synonym: Transport scattering coefficient, Scattering parameter

References:

https://doi.org/10.1117/3.2624517

https://doi.org/10.1117/1.JBO.26.2.026001

https://doi.org/10.1117/12.434505

https://doi.org/10.1364/BOE.2.001687

Related terms: Scattering coefficient, Anisotropy factor

Reflection

Definition: Reflection refers to the mirroring of radiation at an interface between two media with different characteristic impedance (refractive index in optics). A distinction is made between specular reflection from smooth surfaces, in which the radiation is emitted at the same angle at which it is incident, and diffuse reflection from rough surfaces, in which the radiation is diffusely scattered. Diffuse reflection is driven by light that penetrated into the medium and then re-emerged after multiple scattering

Alternative definition:

Synonym:

References:

https://doi.org/10.1088/0143-0807/26/5/022

Related terms:

Refraction

Definition: Refraction is the change in direction of a wave beam, when it passes from one medium to another. This change in direction is due to a difference in the density of the media, which can cause a change in the speed of the waves in the beam. The ratio of the wave speed in the vacuum, c, and the speed of the wave in the medium, v, defines the refractive index of a medium, i.e., $n = \frac{c}{v}$. The angle of refraction can be calculated using Snell’s law.

Alternative definition:

Synonym:

References:

https://doi.org/10.1088/0143-0807/26/5/022

Related terms:

Scattering

Definition: Scattering is the phenomenon by which there is a deflection of moving particles or radiation from their main direction by an interaction with other particles of matter in the medium through which they pass.

Alternative definition:

Synonym:

References:

https://doi.org/10.1117/3.2624517

Related terms: Scattering coefficient

Scattering coefficient

Definition: Scattering coefficient is the ratio between the power scattered in the unit volume and the power incident per unit area; measured in m^{-1}, typically ${mm}^{-1}$ or ${cm}^{-1}$. It is the reciprocal of the average distance traveled by a photon before it undergoes a scattering event within a medium.

Alternative definition:

Synonym: None

References:

https://doi.org/10.1117/3.2624517

Related terms: Reduced scattering coefficient

Spatially resolved spectroscopy

Definition: Spatially Resolved Spectroscopy is derived from the diffusion approximation by differentiating attenuation in respect to distance. The method requires at least two different source detector separations close together with the furthest being at 3cm. The technique is used to estimate absolute scale concentrations of k*HbO_2 and k*Hb and using these to estimate in \% the absolute tissue saturation of tissue $\frac{k*HbO_2}{k*(HbO_2 + Hb} \% $.

Alternative definition:

Synonym: Spatially resolved

References:

https://doi.org/10.1002/jbio.201900064

Related terms:

Spectroscopy

Definition: Spectroscopy is a technique for analyzing and measuring the interaction between electromagnetic radiation and matter. In this process, a spectrometer records the intensity of radiation as a function of energy, frequency or wavelength - the spectrum - after it interacts with or is emitted from a particular material being studied. Since these spectra depend on the absorption and emission properties of the material, and thus on their physical and chemical structure, composition and concentration, they can be used to classify materials.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.jag.2017.10.004

Related terms: Functional Near Infrared Spectroscopy, Spatially resolved spectroscopy

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Temporal point spread function

Definition: The probability to detect photons per unit area and unit time at a given source detector distance ρ and at a given time of flight t.

Alternative definition:

Synonym: Distribution of time of flight (DTOF)

References:

https://doi.org/10.1117/3.2624517

https://doi.org/10.1364/boe.396585

Related terms: Time domain fNIRS

Time-domain near-infrared spectroscopy

Definition: Time-domain near-infrared spectroscopy, in the context of fNIRS, refers to measuring the distribution of photon times of flight through tissue and fitting the resulting histogram to a theoretical model to calculate tissue optical properties, including absorption and scattering coefficients. TD-NIRS, and its Fourier domain analogue swept frequency NIRS, permits gathering a richer data set than either single frequency-frequency domain NIRS or continuous wave NIRS. However, the cost of TD-NIRS hardware per detection channel tends to be higher.

Alternative definition:

Synonym: Time-resolved fNIRS

References:

https://doi.org/10.1088/0031-9155/42/5/007

http://dx.doi.org/10.1016/j.neuroimage.2013.05.106

https://doi.org/10.1117/12.2578518

https://doi.org/10.1364/boe.396585

Related terms: temporal point spread function, diffuse time of flight curve, absorption coefficient, scattering coefficient

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Time of flight

Definition: The time of flight is the time spent by a photon to migrate through tissue from the source to the detector. In time-domain fNIRS, light attenuation is measured by recording the time-of-flight (TOF) of photons through the tissue. A laser is used to emit short pulses of light, and the arrival time of the photons at the detectors is measured. From the resulting distribution, absorption and scattering parameters can be derived.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2013.05.106

https://doi.org/10.1364/boe.396585

Related terms: Time domain fNIRS, Temporal point spread function

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Tissue oxygen saturation

Definition: This term refers to the saturation, or fraction of hemoglobin (expressed in %) bound to oxygen, in the microvasculature of the tissue. It is calculated from NIRS measured absolute deoxyhemoglobin and absolute oxyhemoglobin concentrations as oxyhemoglobin/total hemoglobin. It represents an average of saturation values (in microvessels within the volume sampled by the measurement which are small enough for light to pass through. This includes arterioles, veins and venules, probably in the range of 100-200 μ M. Very large vessels will be thick enough such that all the photons will be absorbed and no signal will be detected from them. The abbreviation was introduced because it matches the accepted format for describing oxygen saturation of hemoglobin in arteries (SaO_2) and veins (SvO_2). The term “t” for tissue was introduced because the data are from a range of vessel types within the microvasculature of the tissue.

Alternative definition:

Synonym: tissue oxygenation, tissue hemoglobin oxygen saturation

References:

http://doi.org/10.1088/0031-9155/46/1/304

https://doi.org/10.1364/boe.412088

https://doi.org/10.1016/S0741-5214(03)01032-2

Related terms:

Tissue Oximetry

Definition: Tissue oximetry with near-infrared light is a non-invasive, optical method that measures blood hemoglobin oxygen saturation in tissue. In particular, it can be used to measure hemoglobin oxygen saturation of a brain region (cerebral tissue oximetry).

Alternative definition:

Synonym:

References:

https://doi.org/10.1213/ANE.0000000000001348

Related terms: Tissue oxygen saturation

Total attenuation coefficient

Definition: When absorption and scattering are considered together then we speak of the total attenuation. If we do not account for multiple scattering then $ total attenuation = absorption + scattering $ Just like there are absorption and scattering coefficients, there is also attenuation or extinction coefficient, which is the sum of the absorption coefficient and the scattering coefficient (not the reduced scattering coefficient). $\mu_t = \mu_a + \mu_s$

Alternative definition:

Synonym: Attenuation

References:

https://doi.org/10.1134/S0030400X11020093

Related terms: Absorption, Scattering, Attenuation

Wavelength

Definition: Wavelength is the distance between corresponding points of a wave separated by one period. It is commonly denoted $\lambdA$, and given by:$ \lambda = \frac{u}{v} $ where u is the wave speed and v is the frequency. In fNIRS, wavelength refers to the specific range of light wavelengths used to measure changes in chromophore concentration in the brain. Typically these are between 650-900 nm.

Alternative definition:

Synonym:

References:

https://doi.org/10.1073/pnas.2208729119

Related terms: Peak Wavelength, Source, Emitter, Chromophore, Optical Window

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Continuous-wave spectroscopy

Definition: Continuous wave (CW) spectroscopy is an fNIRS technique in which light of constant intensity is injected into tissue, and then the attenuated light signal is measured at a distance from the light source. Note, in practice all sources are switched off/on on some timescale; when the on/off time is long compared to relaxation/equilibrium in the sample, then such sources are considered to be continuous from the physics point of view.

Alternative definition: A technique that involves sending near-infrared light at a constant intensity into the tissue and measuring only the intensity of the re-emerging (i.e., diffusely reflected or transmitted) light.

Synonym: continuous-wave spectroscopy

References: T. Jue and K. Masuda. Application of Near Infrared Spectroscopy in Biomedicine. Handbook of Modern Biophysics. Springer US, 2013.

Related terms: Frequency Domain Spectroscopy, Time Domain fNIRS

Frequency-domain near-infrared spectroscopy

Definition: Frequency-domain near-infrared spectroscopy (FD-NIRS) is an fNIRS technique that sinusoidally modulates a near-infrared light source at a given frequency into tissue, and detects the phase shift as well as the attenuation in amplitude with the aim of estimating the absorption and scattering coefficients of the medium. The modulation frequency needs to be higher than the shift induced by the time of light propagation inside the medium (on the order of nanoseconds), which depends on the light speed in the medium. Usually this is on the order of 100 MHz. FD spectroscopy can vary the modulation frequency (Multi-Frequency FD) and measures the amplitude attenuation and phase shift at different frequencies. In some cases, it is possible to measure attenuation and phase at one single frequency and use modeling assumptions to estimate the absorption and scattering coefficients and in turn, quantify chromophore concentrations.

Alternative definition:

Synonym: Frequency-domain spectroscopy, Frequency-domain diffuse optical spectroscopy

References:

https://doi.org/10.1017/CBO9781139029797

Related terms:

Functional Near-Infrared Spectroscopy

Definition: Functional near-infrared spectroscopy (fNIRS) is a non-invasive diffuse optical technique that quantifies changes in measured signals from a single or several source-detector pairs over short periods of time (ranging from seconds to hours) in order to detect functional brain activation. Typically, it is assumed that the changes in light intensity during this temporal range reflect changes in absorption only (i.e., scattering is constant during this period). The changes in absorption can then be related to changes in chromophore concentration such as oxy- and deoxy-hemoglobin, water, and cytochrome c oxidase. fNIRS is performed with continuous-wave spectroscopy devices, as well as frequency-domain and time-domain spectroscopy techniques. In the case of frequency-domain and time-domain systems, it is possible to obtain absolute parameters of optical properties and therefore absolute concentration changes, but this is less commonly performed. fNIRS measurements with multiple measurement channels may use image reconstruction methods, which when done for 2D (topographic) or 3D (tomographic) images falls into the domain of diffuse optical imaging.

Alternative definition:

Synonym:

References:

https://doi.org/10.1016/j.neuroimage.2012.03.049

https://doi.org/10.1016/j.neuroimage.2013.11.033

Related terms: Light absorption, light source, light detectors, continuous wave spectroscopy, infrared spectroscopy

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Modified Beer-Lambert Law

Definition: A common approach to measuring changes in the tissue absorption using continuous waves methods is based on a generalization of Beer-Lambert law in conjunction with the assumption that the scattering properties of tissue do not vary with time. The modified Beer-Lambert law (mBLL) can be expressed as follows:

$$I = I_0 e^{(-\overline{DPF}\mu_a r)-G}$$

Where: I is the detected optical intensity. I_{0} I_0 is the incident intensity. $\overline{DPF}$ is an average (over the absorption range 0- μ_a) mean pathlength factor that depends on the optical properties of tissue $\overline{DPF}$ accounts for the dependence of the mean optical pathlength on scattering and absorption and r is the inter-optode distance. G is a factor that accounts for the effect of scattering and μ_{a} μ_a is the absorption coefficient. By calculating logarithmic ratio of I and I_0 , we estimate the attenuation OD (optical density):

$$A = OD = log_{10}\frac{I_0}{I} = \frac{[D\bar{P}F\mu_a r + G]}{log_e(10)}$$

which is the integral form of the mBLL. It is valid for an arbitrary medium in terms of its geometry and spatial distribution of the scattering coefficient. If we assume that G is constant and that the absorption change in the medium between a baseline condition and a test condition is small compared to μ_{a}, it can be shown that the logarithmic difference between the detected intensity at baseline and during the test condition can be written as follows:

$$\Delta A = \Delta OD = log_{10}(\frac{I_{baseline}}{I_{test}}) = DPF\frac{r\Delta\mu_a}{log_e(10)}$$

where: Differential pathlength factor (DPF) is defined as the ratio of the mean pathlength of detected photons at baseline to the inter-optode distance. The last equation is the differential form of the mBLL and it is valid for an arbitrary medium in terms of its geometry and spatial distribution of the optical properties at baseline. The only requirement is that $\Delta \mu_a$ is spatially uniform. The change in the absorption coefficient $\Delta \mu_a$ is the summation of the changes in the absorption contributions associated with available chromophores in the medium e.g. HbO$_2$ and Hb which are given by the product of their molar decadic absorption coefficients ($\epsilon_{HbO_2}, \epsilon_{Hb}$) and their concentration changes:

$$\Delta\mu_a(\lambda) = log_e(10) \cdot [\epsilon_{HbO_2}(\lambda)\Delta c_{HbO_2} + \epsilon_{Hb}(\lambda)\Delta c_{Hb}]$$

The change in absorbance can then be written for two wavelengths ($ \lambda_1 , \lambda_2 $) and two chromophores (HbO$_2$, Hb) as below, assuming DPF to be independent of wavelength:

$$\Delta A(\lambda_1) = DPF \cdot r \cdot [\epsilon_{HbO_2}(\lambda_1)\Delta c_{HbO_2} + \epsilon_{Hb}(\lambda_1)\Delta c_{Hb}]$$

$$\Delta A(\lambda_2) = DPF \cdot r \cdot [\epsilon_{HbO_2}(\lambda_2)\Delta c_{HbO_2} + \epsilon_{Hb}(\lambda_2)\Delta c_{Hb}]$$

One can estimate the concentration changes of both hemoglobin species by solving this system of linear equations.

Alternative definition:

Synonym: modified Bouguer-Beer-Lambert Law

References:

https://doi.org/10.1039/9781847551207

https://doi.org/10.1088/0031-9155/51/5/N02

https://doi.org/10.1088/0031-9155/33/12/008

https://doi.org/10.1088/0031-9155/49/14/N07

Related terms: Beer Lambert Law, Light Intensity, Molar Absorption