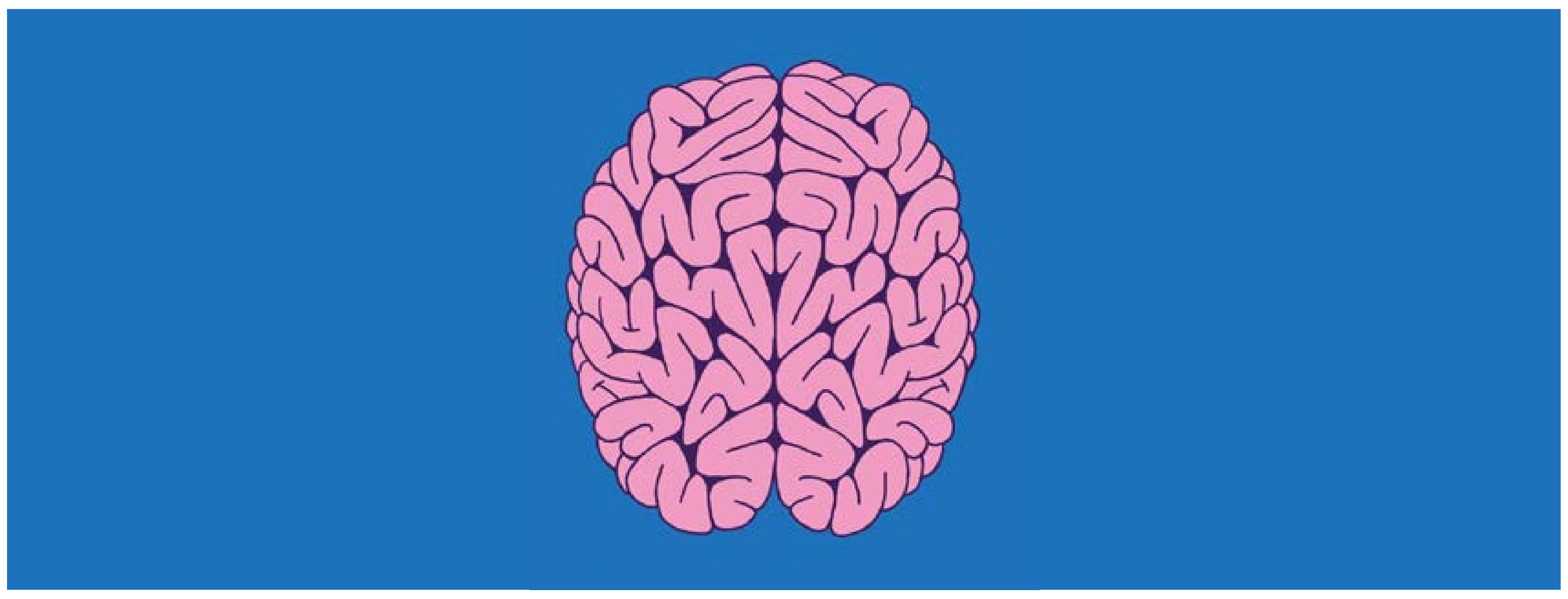
About fNIRS

A non-invasive, portable method employing near-infrared light propagating diffusely through the scalp and brain, for functional monitoring and imaging of human brain hemodynamics.



Functional near-infrared spectroscopy (fNIRS) is an optical brain monitoring technique which uses near-infrared spectroscopy for the purpose of functional neuroimaging. Using fNIRS, brain activity is measured by using near-infrared light to estimate cortical hemodynamic activity which occur in response to neural activity. Alongside EEG, fNIRS is one of the most common non-invasive neuroimaging techniques which can be used in portable contexts. The signal is often compared with the BOLD signal measured by fMRI and is capable of measuring changes both in oxy- and deoxyhemoglobin concentration, but can only measure from regions near the cortical surface. fNIRS may also be referred to as Optical Topography (OT) and is sometimes referred to simply as NIRS.

fNIRS estimates the concentration of hemoglobin from changes in absorption of near infrared light. As light moves or propagates through the head, it is alternately scattered or absorbed by the tissue through which it travels. Because hemoglobin is a significant absorber of near-infrared light, changes in absorbed light can be used to reliably measure changes in hemoglobin concentration. Different fNIRS techniques can also use the way in which light propagates to estimate blood volume and oxygenation. The technique is safe, non-invasive, and can be used with other imaging modalities.

NIRS is a non-invasive imaging method involving the quantification of chromophore concentration resolved from the measurement of near infrared (NIR) light attenuation or temporal or phasic changes. The technique takes advantage of the optical window in which (a) skin, tissue, and bone are mostly transparent to NIR light (700–900 nm spectral interval) and (b) hemoglobin (Hb) and deoxygenated-hemoglobin (deoxy-Hb) are strong absorbers of light.

There are six different ways for infrared light to interact with the brain tissue: direct transmission, diffuse transmission, specular reflection, diffuse reflection, scattering, and absorption. fNIRS focuses primarily on absorption: differences in the absorption spectra of deoxy-Hb and oxy-Hb allow the measurement of relative changes in hemoglobin concentration through the use of light attenuation at multiple wavelengths. Two or more wavelengths are selected, with one wavelength above and one below the isosbestic point of 810 nm—at which deoxy-Hb and oxy-Hb have identical absorption coefficients. Using the modified Beer-Lambert law (mBLL), relative changes in concentration can be calculated as a function of total photon path length.

Typically, the light emitter and detector are placed ipsilaterally (each emitter/detector pair on the same side) on the subject's skull so recorded measurements are due to back-scattered (reflected) light following elliptical pathways. fNIRS is most sensitive to hemodynamic changes which occur nearest to the scalp and these superficial artifacts are often addressed using additional light detectors located closer to the light source (short-separation detectors).

History ⟶

SOURCES:

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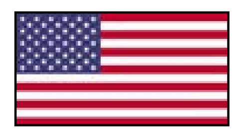
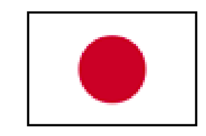
History of fNIRS

The US, UK, and Japan have been at the forefront of developing functional near-infrared spectroscopy technology since the 1970s.

1977

[1977] Jöbsis reported that brain tissue transparency to NIR light allowed a non-invasive and continuous method of tissue oxygen saturation using transillumination. Transillumination (forward-scattering) was of limited utility in adults because of light attenuation and was quickly replaced by reflectance-mode based techniques - resulting in development of NIRS systems proceeding rapidly.

1985

[1985] The first studies on cerebral oxygenation were conducted by M. Ferrari.

[1985] Japanese researchers at the central research laboratory of Hitachi Ltd set out to build a NIRS-based brain monitoring system using a pulse of 70-picosecond rays.

1989

[1989] Following work with David Delpy at University College London, Hamamatsu developed the first commercial NIRS system: NIR-1000 cerebral oxygenation monitor

1990

[1990] NIRS methods were initially used for cerebral oximetry in the 1990s.

1993

[1993] Four publications by Chance et al. PNAS, Hoshi & Tamura J Appl Physiol, Kato et al. JCBFM, Villringer et al Neuros. Lett. demonstrated the feasibility of fNIRS in adult humans.

1995

[1995] This effort came into light when the team, along with their leading expert, Dr Hideaki Koizumi (小泉 英明), held an open symposium to announce the principle of "Optical Topography" in January 1995.

2001

[2001] In fact, the term "Optical Topography" derives from the concept of using light on "2-Dimensional mapping combined with 1-Dimensional information", or topography. The idea had been successfully implemented in launching their first fNIRS (or Optical Topography, as they call it) device based on Frequency Domain in 2001: Hitachi ETG-100.

2003

[2003] Later, Harumi Oishi (大石 晴美), a PhD-to-be at Nagoya University, published her doctoral dissertation in 2003 with the subject of "language learners' cortical activation patterns measured by ETG-100" under the supervision of Professor Toru Kinoshita (木下 微)—presenting a new prospect on the use of fNIRS. The company has been advancing the ETG series ever since.

NIRS techniques were further expanded on by the work of Randall Barbour, Britton Chance, Arno Villringer, M. Cope, D. T. Delpy, Enrico Gratton, and others. Currently, wearable fNIRS are being developed.

⟵ **Description** | **Application** ⟶

SOURCE:

Jöbsis (1997). "Noninvasive, infrared monitoring of cerebral and myocardial oxygen sufficiency and circulatory parameters". Science. 198 (4323): 1264–1267. doi:10.1126/science.929199. PMID 929199

Applications of fNIRS

For more than 20 years, fNIRS has enabled clinicians to gain insight into cerebral development and mechanisms of injury in neonates. fNIRS is a useful supplement to existing technologies due to its ability to interrogate the neonatal brain function.

Brain-Computer Interface

fNIRS has been successfully implemented as a control signal for brain–computer interface systems.

Hypoxia and Altitude Studies

With our constant need for oxygen, our body has developed multiple mechanisms that detect oxygen levels, which in turn can activate appropriate responses to counter hypoxia and generate a higher oxygen supply. Moreover, understanding the physiological mechanism underlying the bodily response to oxygen deprivation is of major importance and NIRS devices have shown to be a great tool in this field of research.

Brain Mapping

Functional Connectivity

fNIRS measurements can be used to calculate functional connectivity. Multi-channel fNIRS measurements create a topographical map of neural activation, whereby temporal correlation between spatially separated events can be analyzed. Functional connectivity is typically assessed in terms correlations between the hemodynamic responses of spatially distinct regions of interest (ROIs). In brain studies, functional connectivity measurements are commonly taken for resting state patient data, as well as data recorded over stimulus paradigms. The low cost, portability and high temporal resolution of fNIRS, with respect to fMRI, have proven to be highly advantageous in studies of this nature.

Cerebral Oximetry

NIRS monitoring is helpful in a number of ways. Preterm infants can be monitored reducing cerebral hypoxia and hyperoxia with different patterns of activities. It is an effective aid in Cardiopulmonary bypass, is strongly considered to improve patient outcomes and reduce costs and extended stays.There are inconclusive results for use of NIRS with patients with traumatic brain injury, so it has been concluded that it should remain a research tool.

Diffuse Optical Tomography

Diffuse optical tomography is the 3D version of Diffuse optical imaging. Diffuse optical images are obtained using NIRS or fluorescence-based methods. These images can be used to develop a 3D volumetric model which is known as the Diffuse Optical Tomography.

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fNIRS Cap

fNIRS electrode locations can be defined using a variety of layouts, including names and locations that are specified by the International 10–20 system as well as other layouts that are specifically optimized to maintain a consistent 30mm distance between each location. In addition to the standard positions of electrodes, short separation channels can be added. Short separation channels allow the measurement of scalp signals. Since the short separation channels measure the signal coming from the scalp, they allow the removal of the signal of superficial layers. This leaves behind the actual brain response. Short separation channel detectors are usually placed 8mm away from a source. They do not need to be in a specific direction or in the same direction as a detector.

Functional Neuroimaging

The use of fNIRS as a functional neuroimaging method relies on the principle of neuro-vascular coupling also known as the haemodynamic response or blood-oxygen-level dependent (BOLD) response. This principle also forms the core of fMRI techniques. Through neuro-vascular coupling, neuronal activity is linked to related changes in localized cerebral blood flow. fNIRS and fMRI are sensitive to similar physiologic changes and are often comparative methods. Studies relating fMRI and fNIRS show highly correlated results in cognitive tasks. fNIRS has several advantages in cost and portability over fMRI, but cannot be used to measure cortical activity more than 4 cm deep due to limitations in light emitter power and has more limited spatial resolution. fNIRS includes the use of diffuse optical tomography (DOT/NIRDOT) for functional purposes. Multiplexing fNIRS

Hyperscanning

Hyperscanning involves two or more brains monitored simultaneously to investigate interpersonal (across-brains) neural correlates in various social situations, which proves fNIRS to be a suitable modality for investigating live brain-to-brain social interactions.

Virtual and Augmented Reality

Modern fNIRS systems are combined with virtual or augmented reality in studies on brain-computer interfaces, neurorehabilitation or social perception.

Music and the Brain

fNIRS can be used to monitor musicians' brain activity while playing musical instruments.

⟵ **History**

Comparison ⟶

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Neuroimaging Technologies

Explore the intricate world of neuroimaging technologies – fNIRS, fMRI, EEG/MEG, and PET – to unravel their unique strengths, weaknesses, and applications in the realm of cognitive research and clinical diagnosis.

	fNIRS Funcational NIR Spectroscopy	fMRI Functional Magnetic Resonance Imaging	EEG/MEG Electroencephalography/ Magnetoencephalography	PET Position Emission Tomography
Signal	HbO_2/HbR	BOLD (HbR)	Electromagnetic	Central Blood Flow Glucose Metabolism
Spatial Resolution	2–3 cm	0.3mm voxels	5–9 cm	4 mm
Penetration Depth	Brain Cortex	Whole Head	EEG: Brain Cortex MEG: Deep Structures	Whole Head
Temporal Sampling Rates	Up to 10 Hz	1–3 Hz	>1000 Hz	<0.1 Hz
Range of Possible Tasks	Enormous	Limited	Limited	Limited
Robustness to Mostion	Very Good	Limited	Limited	Limited
Range of Possible Participants	Everyone	Limited, can be challenging for children/patients	Everyone	Limited
Sounds	Silent	Very Noisy	Silent	Silent
Portability	Yes, for portable systems	None	Yes, for portavble EEG	None
Costs	Low	High	EEG: Low MEG: High	High

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fNIRS Data Analysis Software

Tools for researchers to analyze and interpret functional near-infrared spectroscopy data, enabling the study of brain activity while assisting in data processing, statistical analysis, and visualization.

HOMER3

HOMER3 allows users to obtain estimates and maps of brain activation. It is a set of matlab scripts used for analyzing fNIRS data. This set of scripts has evolved since the early 1990s first as the Photon Migration Imaging toolbox, then HOMER1 and HOMER2, and now HOMER3.

NIRS Toolbox

This toolbox is a set of Matlab-based tools for the analysis of functional near-infrared spectroscopy (fNIRS). This toolbox defines the +nirs namespace and includes a series of tools for signal processing, display, and statistics of fNIRS data. This toolbox is built around an object-oriented framework of Matlab classes and namespaces.

AtlasViewer

AtlasViewer allows fNIRS data to be visualized on a model of the brain. In addition, it also allows the user to design probes which can eventually be placed onto a subject.

⟵ Comparison

Sources ⟶

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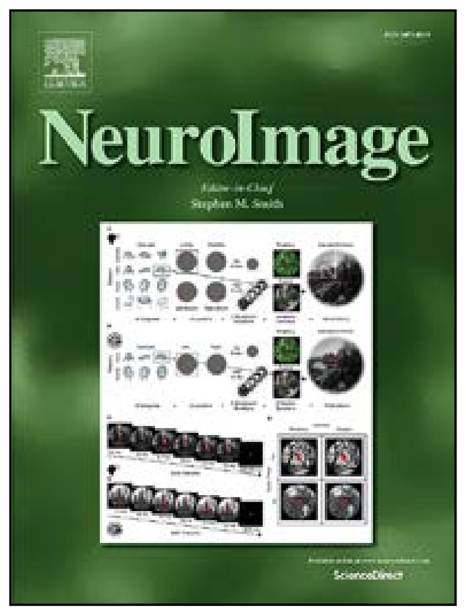
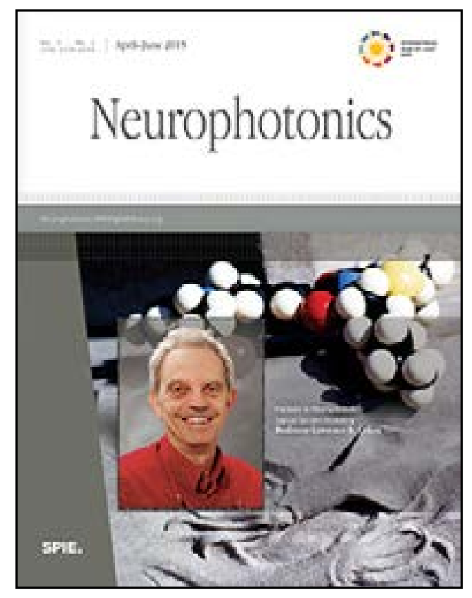
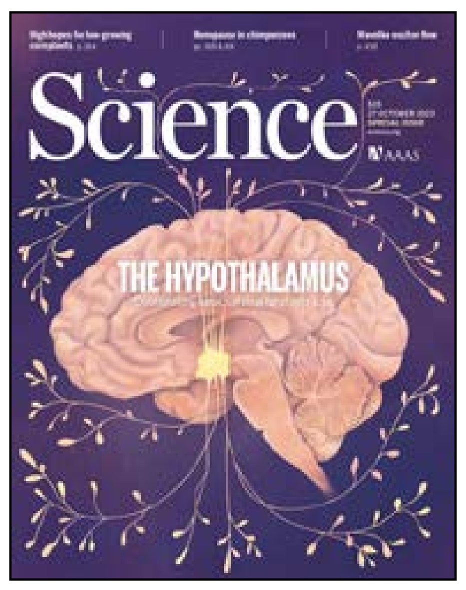
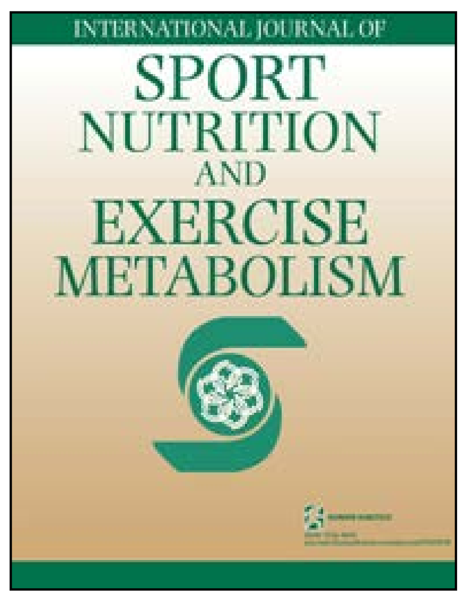
Sources

Among other sources, 16 academic journals were referenced in the creation of this website.









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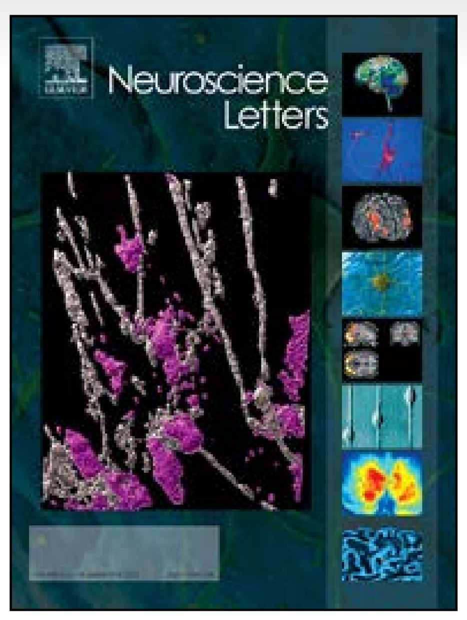
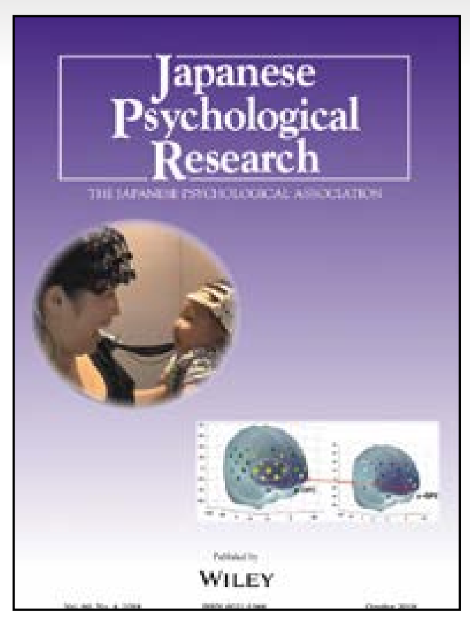
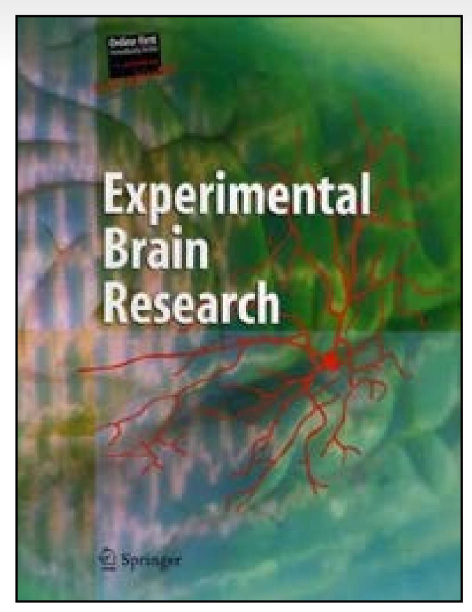
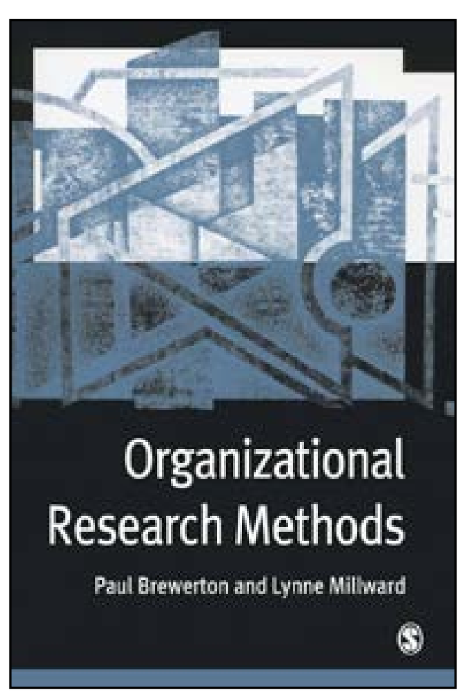
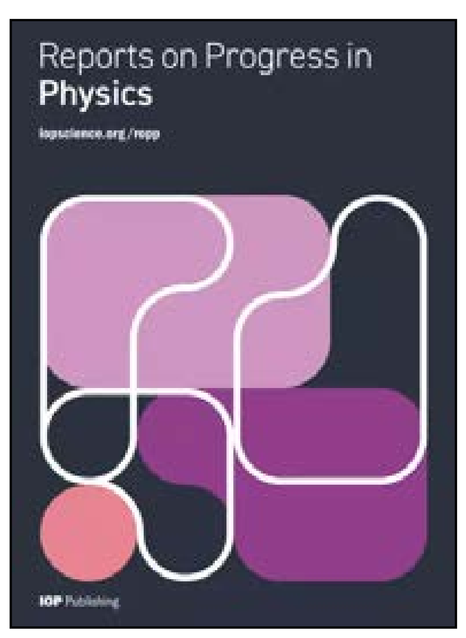
Out of Viewport

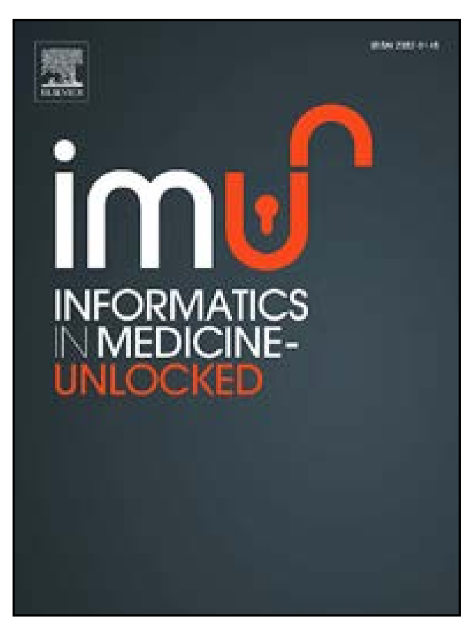












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