Bibliography on the Ethical, Legal, and Social Implications of Emerging Portable and Accessible Neuroimaging Technologies

Last updated: October 17, 2021

Introduction

This bibliography contains resources related to the ethical, legal, and social implications (ELSI) of emerging portable and accessible neuroimaging technologies, as well as selected relevant publications from the scientific and medical literatures. The bibliography is focused specifically on the ELSI of portable and accessible neuroimaging, and does not include citations to broader literatures on ELSI of traditional fixed neuroimaging (e.g. the extensive literature on ELSI of incidental findings in MRI). The bibliography also does not include citations to literature on emerging neurotechnologies beyond brain imaging (e.g. neurostimulation). For more general resources on neuroethics, readers might view the resources page of NIH BRAIN Neuroethics and the resources page of the Global Neuroethics Summit. The bibliography contains selected scientific publications related to emerging portable neuroimaging technologies, but is not exhaustive and generally excludes publications that are more technical in nature.

The bibliography is a product of an NIH RF1 grant: Highly Portable and Cloud-Enabled Neuroimaging Research: Confronting Ethics Challenges in Field Research with New Populations (NIH Grant #RF1MH123698). A web-based version of the Bibliography, as well as more information about the grant, is available online. The grant is based at the University of Minnesota’s Consortium on Law and Values in Health, Environment & the Life Sciences.

The Bibliography is organized by topical area, with entries listed alphabetically within each category by last name of the first author. You can scroll down or click on each topical heading below to jump to a particular section:

- Law and Ethics
- Selected Guidelines
- Neuroimaging in Low-Resource Contexts
- Portable Magnetic Resonance Imaging (MRI)
- Portable Magnetoencephalography (MEG)
- Portable Positron Emission Tomography (PET)
- Portable Functional Near-Infrared Spectroscopy (fNIRS)
- Portable Electroencephalography (EEG)

Contact: The bibliography will be updated regularly, and suggested additions can be sent to Dr. Francis Shen, fxshen@umn.edu.

Acknowledgment: Research reported in this document was supported by the National Institute of Mental Health of the National Institutes of Health under Award Number RF1MH123698. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.
Law and Ethics

Although there are established literatures on the ethics of traditional fixed neuroimaging, the literature specific to the ethical, legal, and social implications of highly portable and accessible neuroimaging is only beginning to emerge.


**Selected Guidelines**

As neuroimaging research moves out of the lab and into the field, neuroimaging researchers will be confronted with novel ethical and technical challenges. The selected guidelines below provide high-level guidance for addressing those challenges.


Participants in the 2006 Georgetown University Workshop on the Ancillary-Care Obligations of Medical Researchers Working in Developing Countries (2008). The Ancillary-Care Obligations of Medical Researchers Working in Developing Countries. *PLOS Med 5*(5), e90. https://doi.org/10.1371/journal.pmed.0050090 PMID: 18494553


**Neuroimaging Research in Low-Resource Contexts**
The increased portability and lower costs of new MRI technologies will allow researchers and clinicians to utilize MRI in low-resource contexts that previously did not have access to MRI. The citations below include articles in which MRI is being used in a wide range of research in low-resource contexts.


**Portable MRI**

Multiple research teams are actively developing more portable and more accessible magnetic resonance imaging (MRI) technologies. These technologies include low-field MRI, ultra-low field MRI, and more portable high-field MRI. The citations below are selected publications describing these technological advances.


Portable MEG

Magnetoencephalography (MEG) measures the magnetic waves created by the brain’s neural activity. Traditional MEG requires a large device, a big liquid helium cooling unit, and a motionless participant. But researchers are now developing portable MEG technology that
relaxes those constraints. The citations below are selected publications describing new, portable MEG.


**Portable PET**

*Positron emission tomography (PET) is a method of indirectly measuring brain function by injecting a radioactive tracer into the bloodstream and then tracking how brain cells consume glucose. Traditional PET technology has required a large machine, with patients flat on their back. But new research is exploring the possibility of more portable and wearable PET technology. The citations below are selected publications describing these advances.*


**Portable fNIRS**

Functional near-infrared spectroscopy (fNIRS) utilizes sensors on the human scalp and optimal imaging to indirectly measure brain function by detecting changes in cerebral blood flow. fNIRS has always been more portable than fixed MRI, MEG, and PET, but new advances are allowing for even more portability at lower costs. The citations below present selected research utilizing portable fNIRS.


Transactions on Biomedical Circuits and Systems, 13(1), 91–102.  
https://doi.org/10.1109/TBCAS.2018.2876089

https://doi.org/10.1109/ICEECCOT43722.2018.9001342

PMID: 32197689

https://doi.org/10.1117/12.2080947

https://doi.org/10.3389/fneur.2019.00536  
PMCID: PMC6540937

https://doi.org/10.1016/j.ohx.2021.e00204

https://doi.org/10.3389/fnhum.2015.00617  
PMCID: PMC6540937

https://doi.org/10.1007/s12264-019-00441-1  
PMCID: PMC7056771

https://doi.org/10.1063/1.5086809  
PMCID: PMC6533110

https://doi.org/10.1117/1.NPh.4.4.041413  
PMCID: PMC5562388

https://doi.org/10.1109/ACCESS.2020.3008748

Portable EEG

Electroencephalography (EEG) was invented in the 1920s and uses electrodes on the scalp to measure the brain’s electrical activity. Relative to the other technologies included in this bibliography, EEG is the most affordable and most portable. EEG is used in a variety of consumer-grade technologies, in technologies designed to monitor and enhance athletes’ performance, and in many field-based research projects. The citations below present a selection
of this portable EEG research, but it should be noted that in the interests of space, much additional portable EEG research is not included here.


