OMB No. 0925-0001 and 0925-0002 (Rev. 10/2021 Approved Through 09/30/2024)

BIOGRAPHICAL SKETCH

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NAME: Giorgio, Bonmassar

eRA COMMONS USER NAME (credential, e.g., agency login): GBONMASSAR

POSITION TITLE: Associate Professor in Radiology

EDUCATION/TRAINING *(Begin with baccalaureate or other initial professional education, such as nursing, include postdoctoral training and residency training if applicable. Add/delete rows as necessary.)*

INSTITUTION AND LOCATION	DEGREE *(if applicable)*	Completion Date MM/YYYY	FIELD OF STUDY
University of Rome, “La Sapienza”	Ph.D.	05/1989	Electrical Engineering
Boston University, Boston, MA	Ph.D.	02/1997	Biomedical Engineering
Harvard Medical School, Cambridge, MA	Postdoctoral	02/2001	Radiology

A. **Personal Statement.**

Dr. Bonmassar is an Associate Professor in Radiology at the Harvard Medical School and the Director of the Analog Brain Imaging (ABI) laboratory for electrophysiology and MRI at the Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital (MGH). As the inventor of the micro transcranial magnetic stimulation (µTMS) technology, he will help with the design of the new m-coil. He will replicate, together with the postdoc, the new TSMS system for FAU since both have experience with amplifier design and manufacturing. He will be able to help to perform electromagnetic, heat, and acoustic simulation studies and test the m-coils. As a PI in this project, Dr. Bonmassar will bring his expertise of over twenty years in bioelectromagnetic modeling and the construction of electrophysiological systems. Bioelectromagnetic modeling allowed Dr. Bonmassar to develop a set of microelectrodes that are completely MRI-invisible, and this discovery led to a paper published in *Science (2008)*. In this paper, together with his colleagues, have investigated the frontal eye field (FEF) as one of several cortical regions thought to modulate sensory inputs for bottom-up gating of frontal signals by electrical microstimulation of subregions in the FEF in monkeys and measured the effects throughout the brain with functional magnetic resonance imaging. <u>In the latest *Science (2019)* publication, EEG-fMRI has been utilized to show that CSF flow increases during sleep. Even though this paper was only published a few months ago, this article has been reported in the altimetric 100 (the 100 articles most cited in 2019), with reports published in 138 news outlets, over 4,000 tweets, and appeared as N. 5 of the altimetric list.</u> Among others, Dr. Bonmassar was the first to report that electromagnetic simulations show that leads implanted in the brain could produce local heating. Despite exciting seminal discoveries and demonstrated potential for simultaneous fMRI/EEG, significant challenges from safety concerns and cross-modal data artifacts have so far limited both the quality of systems offered and their widespread adoption. The PI has demonstrated the basic idea with the development of the first InkCap technology. <u>During InkNet SBIR application, we demonstrated the superior SNR advantages of the InkNet design over existing technologies and developed a high-density cap MRI compatible, and developed a Geodesic tensile structure for the Inknet; a similar structure is proposed in this grant</u>. Furthermore, the PI’s laboratory pioneered the design and manufacturing of MRI-safe microstrips for EEG leads and Deep Brain Stimulation leads (RTS). Dr. Bonmassar has gained a large experience in the field of bioelectromagnetic research and lead as a Principal Investigator in U01, RO1, R21, RO3, R43/44 (SBIR), Shared Instrumentation (S10), Brain Initiative (R01), DoD (ONR and CIMIT/Army) and Whitaker Foundation grants, and Co-Investigator in various NIH and grants involving electrophysiology, Magnetic Resonance Imaging (MRI), numerical simulation and hardware development groundwork for advanced/MRI-compatible electrophysiology. Relevant to the proposed study, D. Bonmassar has pioneered the design, and thin-film manufacturing of MRI-safe microstrips for DBS leads based on metamaterials, a project that is funded by a U01 mechanism, titled “Deep Brain Stimulation System for Magnetic Resonance Imaging,” in which he was a PI.ey references are the following:

a) Fultz N., **Bonmassar G**., Setsompop K., Stickgold R.A., Rosen B.R., Polimeni J.R., L. Lewis. Coupled electrophysiological, hemodynamic, and cerebrospinal fluid oscillations in human sleep. Science. Nov 1 2019. Vol. 366, Issue 6465, pp. 628-631. PMID: 31672896.
b) Serano P, Angelone LM, Katnani H, Eskandar E**, Bonmassar G**. Novel MRI Compatible Stimulation Technology. Nature Scientific Reports. 2015 Apr 29;5:9805. PMID: 25924189.
c) **Bonmassar G**, Lee SW, Freeman DK, Polasek M, Fried SI, et al. Microscopic magnetic stimulation of neural tissue. Nature Communications. 3: 921 2012. PMID: 22735449.
d) Roelfsema PR, Arsenault JT, **Bonmassar G**, Vanduffel W. Bottom-up dependent gating of frontal signals in early visual cortex. Science. 2008 Jul 18;321(5887):414-7. PMID: 18635806.

Ongoing and recently completed projects that I would like to highlight include:

5R01MH111875-04 (Bonmassar)
09/26/2016-06/30/2022 NCE
NIH-NIMH
Micro-TMS Technology for Ultra-Focal Brain Stimulation

5R01EB024343-03 (Bonmassar)
09/12/2017-05/31/2022 NCE
NIH- NIBIB
Dense array image-compatible EEG for enhanced neonatal care

1R01NS120594-01 (Bonmassar, Giorgio)
06/01/2021 - 05/31/2024
NIH-National Institutes of Health
Simultaneous functional MRI and Micro-Magnetic Nervous System Stimulation

Completed
5R21EB016449-02 (Bonmassar/Makris-Multi-PI)
08/01/13-7/31/16 .
NIH
The Virtual Patient Simulator of Patients with Deep Brain Stimulation Implants

1U01NS075026-02
02/1/12-01/31/17
Eskander/Bonmassar Multi PI Leadership
Deep Brain Stimulation System for Magnetic Resonance Imaging

2R44NS071988-03A1
08/01/14-07/31/17
Electrical Geodesics, Inc
High-Field MR-Compatible Dense Array EEG using Polymer Thick Film Circuits

S/C with FHC (PI-Mesires)
04/01/15-03/31/17
1R43MH107037-01A1 (PI of Subcontract)
Instruments for Micro-Magnetic Stimulation of the Brain in Animals

2R01NS037462-14A1 (Ahlfors)
07/01/15-06/30/20
NIH
Spatiotemporal imaging of human visual system processing

B. Positions and Honors

Positions and Employment

1987-1988 Research Assistant in Medical Informatics; Department of Physiology, National Research Center, University of Rome, La Sapienza, Rome, Italy.
1988-1992 Research Assistant in EEG Signal Processing, Department of Physiology, University Tor Vergata, Rome, Italy.
1990-1992 Research Engineer, Ericsson, Inc.
1991-1992 Research Assistant in Circuit Design; Department of Physics, University Tor Vergata, Rome, Italy.
1993-1998 Research Assistant in Image Processing, Department of Cognitive and Neural Systems, Boston University, Boston, MA.
1998-2000 Research Fellow, Department of Radiology, Massachusetts General Hospital, HMS.
1998 Assistant in Neurology, Department of Radiology, MGH NMR Center, HMS.
2003- Adjunct Professor of Biomedical Engineering, Tufts University.
2001-2005 Instructor in Radiology, Massachusetts General Hospital, Harvard Medical School.
2005- Assistant in Neuroscience, Massachusetts General Hospital,
2005-2017 Assistant Professor, Harvard Medical School.
2008-2009 IPA for Naval Submarine Medical Research Laboratory (NSMRL), Department of the Navy.
2017- Associate Professor in Radiology, Harvard Medical School.
2020- Faculty of the HMS Division of Sleep Medicine

<u>Honors</u>

1992 National Research Council Award, Committee for Engineering Science and Architecture, Italy.
1993 Graduate Honor Scholarship Award, College of Engineering, Boston University.
1994 National Research Council Award, Committee for Engineering Science and Architecture, Italy.
1996 Alfa Eta Mu Beta Award, Biomedical Engineering Research Society, Boston University.
1999 NATO and National Research Council Advanced Fellowship Award.
2020 Academy for Radiology & Biomedical Imaging Research Distinguished Investigator Award.

C. Contributions to Science

1. ***<u>The inventor of Depth electrodes metamaterials</u>***. Despite its remarkable success, one of the significant limitations of Deep Brain Stimulation (DBS) is its incompatibility with magnetic resonance imaging (MRI). In this project, we design, develop and test novel MRI conditional leads based on resistive tapered stripline technology. The innovative high-resistance technology allows for decreased Specific Absorption Rate. It reduces MRI and CT data artifacts while maintaining low lead resistivity for continuous current injection. Electromagnetic numerical simulation was used to support the design and will be tested thoroughly on rats for biocompatibility. This project's long-term goal is the development of epilepsy systems compatible with MRI and other external radiofrequency sources, with significant benefits to patients that may require neural implantations in pathological conditions such as epilepsy, Parkinson's disease, and stroke.
   a) **Bonmassar G**. Resistive tapered stripline (RTS) in EEG recordings during MRI. IEEE Trans on Microw Theory and Technol 2004, 52(8): 1992-1998.
   b) Serano P, Angelone LM, Katnani H, Eskandar E**, Bonmassar G**. Novel MRI Compatible Stimulation Technology. Scientific Reports. 2015 Apr 29;5:9805. PMID: 25924189.
   c) Laleh Golestanirad, John Kirsch, **Bonmassar G**, et al. "RF-induced heating in tissue near bilateral DBS implants during MRI at 1.5 T and 3T: The role of surgical lead management" NeuroImage, Volume 184, 2019, Pages 566-576. PMID: 30243973.
   d) Jeong H, Ntolkeras G, Alhilani M, Atefi SR, Zöllei L, Fujimoto K, Pourvaziri A, Lev MH, Grant PE, **Bonmassar G**. Development, validation, and pilot MRI safety study of a high-resolution, open source, whole body pediatric numerical simulation model. PLoS One. 2021 Jan 13;16(1):e0241682. doi: 10.1371/journal.pone.0241682. PMID: 33439896.

2. ***<u>The inventor of Cortical Grids Metamaterials.</u>*** In patients requiring brain surgery, intracranial electrocortical (ECoG) recording and stimulation can provide unique knowledge about a patient's functional brain anatomy, including measurement of neuropathic electrical activity (e.g., epileptic spikes and seizures). ECoG may allow for brain function mapping through temporary disruption or activation using electrocortical stimulation (ECS). Standard intracranial electrodes cause significant artifacts in CT and MRI images, and concern about

safety risks such as cortical heating has generally precluded obtaining additional diagnostic MRIs in patients after electrode implantation. He has developed and tested a novel MRI-conditional and biocompatible cortical electrode grid using polymer thick film organic substrate (PTFOS) technology. The MR-conditional PTFOS cortical electrode grid is patient-specific, organic-absorbable, stretchable, and conformable for optimal biocompatibility, safety, and performance. In the longer term, we will extend the technology to provide significant benefits to patients with central nervous system injury who may require neural implantations for brain-machine interfaces, pain treatment, cochlear implants, bionic eyes, deep-brain stimulators, and pacemakers.

a) Roelfsema PR, Arsenault JT, **Bonmassar G**, Vanduffel W. Bottom-up dependent gating of frontal signals in early visual cortex. Science. 2008;321(5887):414-417. PMID: 18635806.
b) **Bonmassar G**, Fujimoto K, and Golby A, PTFOS: Flexible and Absorbable Intracranial Electrodes for Magnetic Resonance Imaging. PLoS ONE 7(9): e41187. doi:10.1371/journal.pone. 2012. PMID: 22984396.
c) Iacono, M.I., et al., **Bonmassar G.** A Study on the Feasibility of the Deep Brain Stimulation (DBS) Electrode Localization Based on Scalp Electric Potential Recordings. Front Physiol, 2018. 9: p. 1788. PMID: 30662407.
d) Ahmadi E, Katnani HA, Besheli, LD, Gu Q, Atefi R, Villeneuve MY, Eskandar E, Lev MH, Golby AJ, Gupta R**, Bonmassar G**. An electrocorticography grid using conductive nanoparticles in a polymer-thick film on an organic substrate improves CT and MR imaging. Radiology. 2016 Aug;280(2):595-601. PMID: 26844363.

3**.** ***<u>The inventor of microscopic magnetic stimulation.</u>*** Recently, Dr. Bonmassar has introduced a novel technology termed micro-magnetic stimulation (μMS) that has proven effective at activating the rodent's local neural circuitry. Moreover, it has been demonstrated that the orientation of the applied μMS fields (relative to the excitable tissue) provides unique activation of neuronal elements not seen with traditional electrical stimulation, a property that can be leveraged to improve experimental or therapeutic goals. In our preliminary data, we demonstrate that this technology can activate neuronal circuitry on the systems level, using an in-vivo rodent preparation. Specifically, the application of micro-magnetic fields in the vicinity of the dorsal cochlear nucleus (DCN) trans-synaptically activates inferior colliculus (IC) neurons. (*: equal contribution).

a) **Bonmassar G**, Lee SW, Freeman DK, Polasek M, Fried SI, et al. Microscopic magnetic stimulation of neural tissue. Nature Commun 3: 921 2012. PMID: 22735449.
b) Park H-J*, **Bonmassar G***, Kaltenbach JA, Machado AG, Manzoor NF, Gale JT. Activation of the central nervous system induced by micro-magnetic stimulation. Nature communications. 2013;4. doi: 10.1038/ncomms3463. PMID: 24030203.
c) Jeong H, Deng J., **Bonmassar G.** Planar figure-8 coils for ultra-focal and directional Micromagnetic Brain Stimulation. Journal of Vacuum Science and Technology B. Journal of Vacuum Science & Technology B 39, 063202 (2021); PMID: 34692236.
d) Jeong H, Cho A., Ay I, **Bonmassar G.** *Short-pulsed micro-magnetic stimulation of the vagus nerve.* Front. Physiol., 07 October 2022 doi:10.3389/fphys.2022.938101

4. ***<u>The inventor of the InkNet technology for EEG/fMRI</u>****.* There have been exciting seminal discoveries that demonstrated the potential for simultaneous fMRI/EEG. However, significant challenges from safety concerns and cross-modal data artifacts have so far limited both the quality of systems offered and their widespread adoption. The InkNet technology, invented by Dr. Bonmassar, is currently being developed as a commercial product under an SBIR (Electrical Geodesic Inc., Eugene, OR) and will be able to address this issue by allowing dense spatial sampling of EEG (hdEEG) to be performed in conjunction of high-field MRI. He has demonstrated the basic idea with the development of the first InkCap technology and constructed an electrophysiological system compatible with MRI, including an open HW/SW EEG/MRI system called "High Field One", which is now available for free download of complete schematics, PCB layout, and SW Labview/Firmware.

a) Poulsen C, Wakeman DG, Atefi SR, Luu P, Konyn A, **Bonmassar G**. Polymer Thick Film Technology for Improved Simultaneous dEEG/MRI Recording: Safety and MRI Data Quality. Magnetic Resonance in Medicine. Volume 77, Issue 2, February 2017, Pages 895-903 PMID: 26876960.
b) S. R. Atefi, P. Serano, C. Poulsen, L. M. Angelone and **Bonmassar G**, "Numerical and Experimental Analysis of Radiofrequency-Induced Heating Versus Lead Conductivity During EEG-MRI at 3 T," in *IEEE*

Transactions on Electromagnetic Compatibility, 2018. doi: 10.1109/TEMC.2018.2840050. PMID: 31210669

c) Jeong H., Ntolkeras G., Grant PE and **Bonmassar G.**, "Numerical Simulation of the Radiofrequency Safety of 128-Channel hd-EEG Nets on a 29-Month-Old Whole-Body Model in a 3 Tesla MRI," in *IEEE Transactions on Electromagnetic Compatibility*, 2021. doi: 10.1109/TEMC.2021.3097732. PMID: 34675444

d) Setzer, B., Fultz, N.E., Gomez, D.E.P. et al. A temporal sequence of thalamic activity unfolds at transitions in behavioral arousal state. Nat Commun 13, 5442 (2022). doi:10.1038/s41467-022-33010-8.

e) Ntolkeras G., Jeong H., Grant PE, and **Bonmassar G.**, "A High-Resolution Pediatric Female Whole-Body Numerical Model With Comparison To A Male Model" in Physics in Medicine and Biology. In Print

5. ***The inventor of the Electrical Impedance Spectroscopy system for stroke detection.*** Dr. Bonmassar has developed an instrument for stroke detection based on electrical impedance spectroscopy (EIS). Current diagnostic neuroimaging for intracranial hemorrhage (ICH) is limited to fixed facilities requiring transport and infrastructural support. ICH diagnosis would benefit from a portable diagnostic technology such as Electrical Bioimpedance. Through simulations and patient observation, we have shown the influence of unilateral ICH hematomas on quasisymmetric scalp potential distribution in order to support the feasibility of bioimpedance technology as a potential early diagnostic tool.

a) **Bonmassar G.**, Iwaki S, Golmaker G., Angelone L., Belliveau JW, and Lev MH, On the Measurement of Electrical Impedance Spectroscopy (EIS) of the Human Head. International Journal of Bioelectromagnetism 2010;12(1):32-46. PMID: 21152370.

b) **Bonmassar G**, Lev M. Improved Sensing Pulses for Increased Human Head Depth Measurement Sensitivity With Electrical Impedance Spectroscopy. IEEE Transactions on Biomedical Engineering 2013;12(60):3306-3313. PMID: 24043365.

c) Seyed RA, Seoane F, Kamalian S, Rosenthal ES, Michael H. Lev MH, **Bonmassar G**. Intracranial Haemorrhage Alters Scalp Potential Distribution in Bioimpedance Cerebral Monitoring: Preliminary Results from FEM Simulation on a Realistic Head Model and Human Subjects. Medical Physics. Med Phys. 2016 Feb;43(2):675. doi: 10.1118/1.4939256. PMID: 26843231.

d) Mareyam, A.; Shank, E.; Wald, L.L.; Qin, M.K.; **Bonmassar, G**. A New Phased-Array Magnetic Resonance Imaging Receive-Only Coil for HBO2 Studies. Sensors 2022, 22, 6076. doi:10.3390/s22166076