

Curriculum Vitae: updated January 14, 2022

I. IDENTIFYING DATA

Name Corey J. Keller, MD, PhD
Current Position Assistant Professor
Current Affiliation Stanford University

II. EDUCATION HISTORY

Colleges and Universities Attended

2007 B.S. with Honors, Biomedical and Electrical Engineering, Tufts University
2009 M.S. with Honors, Biomedical Engineering, Harvard (research), Tufts (coursework)
2015 Ph.D., Neuroscience, Albert Einstein College of Medicine
2015 M. D., Albert Einstein College of Medicine

Residency and Fellowship Training

2015 – 2019 Residency, Department of Psychiatry and Behavioral Sciences, Stanford University
2019 Postdoctoral Fellowship, Department of Psychiatry and Behavioral Sciences, Stanford University

Board Certification

2020 Diplomate, American Board of Psychiatry and Neurology

III. EMPLOYMENT

Academic Appointments:

12/2019-Present Assistant Professor of Psychiatry and Behavioral Sciences
Stanford University School of Medicine
Assistant Professor
VA Palo Alto Health Care System
07/2019-12/2019 Instructor of Psychiatry
Stanford University School of Medicine

Other Appointments:

02/2021– present Investigator

Sierra-Pacific Mental Illness Research Education and Clinical Center (MIRECC)
VA Palo Alto Health Care System

Deputy Director
Precision Neuromodulation Clinic
VA Palo Alto Health Care System

12/2019-11/2020 Co-Founder and Chief Medical Officer, Alto Neuroscience, Inc

IV. HONORS AND AWARDS

2019 NIH DP5 Early Independence Award
2019 NIH K23 Mentored Patient-Oriented Research Career Development Award
2019 BWF Career Award for Medical Scientists (CAMS)
2018 Alpha Omega Alpha Medical Honor Society
2018 Stanford Society of Physician Scholars Collaborative Research Fellowship
2018 NIMH T32 Postdoctoral Fellowship
2018 Career Development Institute for Psychiatry
2017 NIMH Outstanding Resident Award
2017 ASCP New Investigator Award
2017 Winter Conference on Brain Research Travel Fellowship
2017 Society of Biological Psychiatry Early Career Investigator Travel Award
2016 BrainBox Neuroscience Initiative Young Investigator Award
2016 Alpha Omega Alpha Postgraduate Research Award
2015 American Society of Clinical Psychopharmacology Fellowship for Clinical Trials
2015 Stanford Society of Physician Scholars Collaborative Research Fellowship
2014 Society of Biological Psychiatry Medical School Scholar
2014 NINDS Combining Clinical and Research Careers in Neuroscience Travel Award
2013 Albert Einstein College of Medicine Senior Research Fellowship
2011-2015 Neural Systems and Behavior Course Endowed Scholarship Fund Ruth L.
Kirschstein National Research Service Award Medical Scientist Training Program Pre-Doctoral
2010-2011 Fellowship
2009 Epilepsy Foundation Pre-Doctoral Research Training Fellowship
2009 Albert Einstein College of Medicine Grant for Summer Research
2007 Master's Thesis Highest Honors
2007 Magna Cum Laude and Senior Thesis Highest Honors
2004-2007 Eta Kappa Nu – Electrical Engineering Honors Society
Dean's List Honors, Tufts University

Current and Past Memberships in Professional Organizations

2019- Member, ISCTM AI/Machine Learning Working Group
2019- Member, StartX Entrepreneurial Incubator
2018- Member, Alpha Omega Alpha Medical Honors Society
2016- Member, Clinical TMS Society
2016- Member, Society of Physician Entrepreneurs
2015- Member, Human Brain Mapping
2015- Member, International Neuromodulation Society
2015- Member, Society of Biological Psychiatry
2013- Alumnus, Woods Hole MBL Neural Systems and Behavior Course
2009- Member, Society for Neuroscience
2009- Member, American Epilepsy Society
2009- Member, American Medical Association

V. GRANT FUNDING

Current:

2021-2025 **R01MH126639-02**
Funder: NIMH (R01/DP5)
Closing the loop: Development of real-time, personalized brain stimulation
The major goal of this grant is to develop a non-invasive personalized brain stimulation platform for neuropsychiatric disorders
Role: PI

2021-2026 **R01 MH129018-01**
Funder: NIMH
CRCNS US-France Research Proposal: Probing the Dorsolateral Prefrontal Cortex and Central Executive
The major goal of this grant is to optimize TMS procedures for depression by analyzing brain responses from TMS/EEG experiments and direct cortical stimulations in SEEG.
Role: MPI

2021-2026 **Career Award for Medical Scientists**
Funder: Burroughs Wellcome Foundation
Closing the loop: Development of real-time, personalized brain stimulation
Role: PI

2021-2026 **5R01-MH122754-02**
Funder: NIH (NIMH) Williams (PI)
Utilizing changes in human brain connectivity to establish a dose-response relationship involved in the therapeutic actions of prefrontal brain stimulation on depression symptoms
The major goal of this grant is to elucidate the nature of the connectivity changes produced by applying accelerated theta burst stimulation.
Role: Co-I

2021-2025 **1R01-MH125160**
Funder: NIH (NIMH) Williams (PI)

Effects of Stanford Accelerated Intelligent Neuromodulation Therapy on Explicit and Implicit Suicidal Cognition

The major goal of this grant is to elucidate the nature of the suicidal cognition changes produced by applying accelerated theta burst stimulation in acutely suicidal inpatients.

Role: Co-I

Submitted:

2022-2027

1R01 MH129347-01

Funder: NIMH

Investigating the neural mechanisms of repetitive brain stimulation with invasive and noninvasive electrophysiology in humans

Role: MPI

The goal of this project is to characterize the key signatures of the brain's response to theta burst stimulation (TBS) with an unparalleled combination of spatial and temporal resolution using intracranial recordings (Aim 1), link intracranial and non-invasive EEG measures (Aim 2), and investigate how EEG measures derived from intracranial recordings relate to clinical outcome in TBS treatment for depression.

2022-2023

R01 AG078237

Funder: NIA (PI Cheng)

rTMS as a Treatment for Preclinical Alzheimer's Disease

Role: Co-I

2022-2027

R01 MH129694-01

Funder: NIMH (PI Zhang)

Establishing Multimodal Brain Biomarkers Using Data-driven Analytics for Treatment Selection in Depression

Role: Co-I

Completed:

2020

R44MH123373

Funder: NIMH (R44 SBIR) (PI Etkin)

Validation of Machine Learning-Based Treatment Biomarkers in Depression

Role: Co-I

2018-2019

K23MH118466

Electrophysiological basis of cortical plasticity in repetitive transcranial magnetic stimulation

Funder: NIMH (K23)

Role: PI

2019

Funder: NIMH (T32)

Role: Postdoctoral Fellow (PI: Alan Schatzberg)

2011-2015

F31 NS080357

Funder: NINDS (F31)

Localizing functional and pathological networks in epilepsy

Role: PI

2010-2011 Funder: Epilepsy Foundation
Localizing networks with evoked potentials and resting state fMRI
Role: PI

2011-2013 Funder: NINDS (T32)
Medical Scientist Training Program Pre-Doctoral Fellowship
Role: Graduate Student

2018-2019 Funder: Stanford
Modeling of human neuroplasticity following repetitive stimulation
Role: PI

2016-2018 Funder: AOA
AOA Postgraduate Award

2016-2017 Funder: Stanford
Induction and quantification of long-term plasticity in the human brain
Role: PI

VI. PATENTS

1. **Keller CJ**, Etkin A, Wu W. Use of a brain-based signal for predicting and guiding brain stimulation treatment in depression. U.S. Patent Application 41243-520P01US, filed April 2016. Patent Pending.
2. Etkin A, **Keller CJ**, Wu W. Artifact Rejection for Transcranial Magnetic Stimulation Electroencephalogram Data. U.S. Patent Application 41243-520P02US, filed December 2016. Patent Pending.

VII. EDITORIAL SERVICE

Editorial Positions

Frontiers Neuroscience (Guest Editor) 2020, 2021

Ad-Hoc Reviewer

Nature Communications, PNAS, Journal of Neuroscience, Neuropsychopharmacology, Human Brain Mapping, Neuroreport, IEEE Transactions on Biomedical Engineering, Neuroscientist, Journal of Psychiatric Research, Brain Topography

VIII. SERVICE AS A GRANT REVIEWER

National Scientific Committees and Grant Review

NIH: NINDS Translational Neural Devices (ZN21 SRB-S-03): Neural, Brain, and Pain Relief Devices, November, 2019, Bethesda, MD.

NIH: ZRG1 ETTN-D (91): Special Topics: Noninvasive Neuromodulation and EEG/MEG

Neuroimaging, March 2021

NIH: ZRG1 ETTN-D (91): Special Topics: Noninvasive Neuromodulation and EEG/MEG
Neuroimaging, February 2022

IX. UNIVERSITY ADMINISTRATIVE SERVICE

Reading Committee:

Jeffrey Wang, PhD Candidate, BioEngineering Program

Qualification Committee:

Christopher Minasi, PhD Candidate, Neuroscience Program

Rotational Students:

Benyamin Meschede-Krasa, PhD Candidate, Neuroscience Program

Christopher Minasi, PhD Candidate, Neuroscience Program

Stanford Committees

2021-Present. Associate Training Director, Psychiatry Residency (Research Track)

2021-Present Member, PAVIR, VA and Stanford Integrated Committee (PVSIC)

Stanford Teaching

04/09/2021

Neuroimaging

Guest lecture in Stanford Neuroscience Resident Course

X. INVITED PRESENTATIONS (SINCE 2013)

National

1. Keller, CJ (2022) *Modifying human neural circuits with precision neurotherapeutics. NIH Brain Initiative: Human Neuroscience and the Cross-Cutting Impact of Scientific Collaboration: Labroots Neuroscience conference.*
2. Keller, CJ (2022). *Modifying human neural circuits with precision neurotherapeutics. University of Pennsylvania Center for Neuromodulation in Depression and Stress Seminar Series.*
3. Keller, CJ (2020). *Transforming the Practice of Mental Health Care: The Desired Future State. NIMH Virtual Symposia.*
4. Keller, CJ (2019). *Towards Personalized Brain Stimulation for Neuropsychiatric Disorders. Conte Center Series Symposium, Columbia University, New York, NY.*
5. Keller, CJ (2019). *Towards Personalized Brain Stimulation for Neuropsychiatric Disorders. Innovations in Psychiatry Symposium, Mt. Sinai School of Medicine, New York, NY.*
6. Keller, CJ (2018). *Towards Personalized Neuromodulation. McLean Hospital, Harvard Medical School, Boston, MA.*
7. Keller, CJ (2015). *Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays. Massachusetts General Hospital, Harvard Medical School, Boston, MA.*
8. Keller, CJ (2015). *The neural origins of the default mode network and resting fMRI. New York Psychiatric Institute, Columbia University Medical Center, New York.*
9. Keller, CJ (2014). *Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays. The Feinstein Institute for Medical Research, Manhasset, New York.*
10. Keller, CJ (2014). *Testing propagation of brain stimulation with implanted electrode arrays. Berenson-Allen Center for Brain Stimulation, Harvard Medical School, Boston.*

International

11. Keller, CJ (2019). *Towards Personalized Brain Stimulation for Neuropsychiatric Disorders. 3rd International Forum on Brain Dysfunction and Neuromodulation, Shenzhen University, Shenzhen, China.*
12. Keller, CJ (2016). *Long-term plasticity underlies antidepressant effect of repetitive transcranial magnetic stimulation. 1st International Forum on Brain Dysfunction and Neuromodulation Shenzhen University, Shenzhen, China.*
13. Keller, CJ (2016). *Modifying neural circuits with brain stimulation. University of Milan, Milan, Italy.*

14. Keller, CJ (2013). *The electrophysiological signature of the DMN*. Weizmann Institute, Rehovot, Israel.

Regional

15. Keller, CJ (2020). *Towards Personalized Brain Stimulation for Neuropsychiatric Disorders*. UCSD, Markou Seminar, San Diego, CA.

16. Keller, CJ (2015). *Investigating the neuronal mechanisms underlying repetitive brain stimulation with implantable microelectrode arrays*. Stanford University, Palo Alto.

XI. TRAINEES

Current Postdoctoral Fellows and Residents

Name	Position @ Keller Lab	Primary Affiliation	Project topics
Christopher Cline, PhD	Staff Scientist	Stanford University	Closed-loop TMS-EEG
Sara Parmigiani, PhD	Staff Scientist	Stanford University	TMS, EEG, depression
Austin Talbot, PhD	Post-doc	Stanford University	depression, biomarkers, EEG
Sergei Tugin, PhD	Post-doc	Stanford University	Real-time TMS-EEG
Jessica Ross, PhD	Post-doc	Stanford University	TMS, EEG, sensory effects
Camarin Rolle, PhD	Post-doc	Stanford University	iEEG, brain networks
Jennifer Lissemore, PhD	Post-doc	Stanford University	OCD, TMS-EEG
Francesco Donati	Collaborating Post-doc	University of Milan	TMS, EEG, brain networks

Current Graduate Students

Name	Position @ Keller Lab	Primary Affiliation	Project topics
Jeffrey Wang	Collaborating Neuroscience Graduate Student	MD/PhD Candidate, Bioengineering, Stanford	TMS, iEEG
Christopher Minasi	Neuroscience Graduate Student	PhD Candidate, Neuroscience	Electrical stimulation, iEEG
Ossama Abu-Halawa	Collaborating Neuroscience Graduate Student	MD/PhD Candidate, Bioengineering, U of Iowa	Electrical stimulation, iEEG

Current Research Assistants

Name	Position @ Keller Lab	Primary Affiliation	Project topics
Manjima Sarkar	Clinical Research Coordinator	Stanford University	TMS, EEG
Jade Truong	Clinical Research Coordinator	Stanford University	TMS, EEG

Current Undergraduate Students

Name	Position @ Keller Lab	Primary Affiliation	Project topics
Jessica Yang	Undergraduate	Stanford University	depression, TMS
Naryeong Kim	Undergraduate	Stanford University	CCEPs, plasticity
Gayathri Ganesan	Undergraduate	Stanford University	CCEPs, plasticity
Saachi Munot	Undergraduate	Stanford University	CCEPs, plasticity
Ciara Gibbs	Undergraduate	Imperial College London	TMS, plasticity

Former Trainees

Former Undergraduate, Post-Baccalaureate and Graduate Students

Name	Position @ Keller Lab	Years @ Keller Lab	Current Location	Project topics
Christopher Minasi	Rotating Graduate Student	Winter 2021	PhD Student, Stanford	TMS, EEG, epilepsy
Claudia Tischler	Collaborating Research Assistant	2020	MD/PhD Student, Baylor	TMS, EEG, depression

Former Postdoctoral Fellows and Residents

Name	Position @ Keller Lab	Years @ Keller Lab	Current Location	Project topics
Danny Huang	Medical Student	1	Neurosurgery Resident, Stanford	Electrical stimulation, epilepsy, iEEG brain networks
Lewis Kerwin	Medical Student	1	Psychiatry Resident, U of Washington	TMS, EEG, reliability, plasticity

XII. CLINICAL TRIALS

1. **NCT04388202.** Leveraging EEG for Antidepressant Prediction With Sertaline and Escitalopram (LEAP-SE). Role: Principal Investigator.
2. **NCT02843373.** Brain-Based Biomarkers in Response to TMS in MDD. Role: Co-Investigator.
3. **NCT02479906.** A Safety and Efficacy Study with Deep Transcranial Magnetic Stimulation for the Treatment of Post-Traumatic Stress Disorder (PTSD). Role: Co-Investigator.

XIII. BIBLIOGRAPHY

Peer-reviewed original research (25 published, 10 under review)

1. Isserles M, Tendler A, Roth Y, Bystritsky A, Blumberger DM, Ward H, Feifel D, Viner L, Duffy W, Zohar J, **Keller CJ**, Bhati MT, Etkin A, George MS, Filipcic I, Lapidus K, Casuto L, Vaishnavi S, Stein A, Deutsch L, Deutsch F, Morales O, Daskalakis ZJ, Zangen A, Ressler KJ. *Deep Transcranial Magnetic Stimulation Combined With Brief Exposure for Posttraumatic Stress Disorder: A Prospective Multisite Randomized Trial*. **Biol Psychiatry**. 2021 Nov 15;90(10):721-728.
2. Huang Y, Kakusa B, Feng A, Shivacharan R, Lee EB, Kuijper FM, Barbosa DA, Parker JJ, Bohon C, **Keller CJ**, Halpern CH. *The insulo-opercular cortex encodes food-specific content under controlled and naturalistic conditions*. **Nature Communications** 12 (2021):3609.
3. Huang Y, Feng A, Barbosa AN, Gattas S, Shivacharan R, Lee EB, Kuijper FM, Saluja S, Parker JJ, Miller KJ, **Keller CJ**, Bohon C, Halpern CH. *Anticipatory Human Subthalamic Area Beta-band Power Responses to Dissociable Tastes Predict Weight Gain*. **Neurobiology of Disease** 7 (2021): 105348.
4. Huang D[#], Herrero J, Entz L, Fabo D, Hajnal B, Mehta A, **Keller CJ***. *Intracortical dynamics underlying repetitive stimulation predicts changes in network connectivity*. **Journal of Neuroscience**. 31 (2019): 6122-6135.
*Corresponding author
#Medical student mentee
5. Eshel N*, **Keller CJ***, Wu W, Jang J, Huemer J, Mills-Finnerty C, Wright R, Ichikawa N, Fonzo G, Sphigel S, Wong M, Yee A, McTeague L, Etkin A. *Global connectivity and local excitability changes underlie antidepressant effects of repetitive transcranial magnetic stimulation*. 2019. **Neuropsychopharmacology**. 2020; 45(6):1018-1025.
*First author with equal contributions
6. Etkin A, Fonzo G, Huemer J, Patenaude B, Vertes P, Richiardi J, Goodkind M, **Keller CJ**, et al. *Using fMRI connectivity to define a treatment-resistant form of post-traumatic stress disorder*. **Science Translational Medicine**. 2019 Apr 3;11(486). **Impact: 16.7**.
7. **Keller CJ**, Huang D, Honey CJ, Du V, Fini M, Lado FA, Mehta AD. *Induction and quantification of excitability changes in human cortical networks*. **Journal of Neuroscience**: 23 (2018): 5384-98.
8. **Keller CJ***, Wu W*, Rogasch NC, Longwell P, Spigel E, Rolle CE, Etkin A. *ARTIST: A Fully Automated Artifact Rejection Algorithm for Single-Pulse TMS-EEG Data*. **Human Brain Mapping**. 00 (2018): 1-19. **Impact: 5.9**. *These authors contributed equally.
9. **Keller CJ***, **Kerwin L***, Wu W, Etkin A. *Test-Retest Reliability of Transcranial Magnetic Stimulation EEG Evoked Potentials*. **Brain Stimulation**: 3 (2018): 536-44. *These authors contributed equally.

10. Megevand P, Groppe DM, Bickel S, Mercier M, Goldfinger MS, **Keller CJ**, Entz L, Mehta AD. *The hippocampus and amygdala are integrators of distributed neocortical influence: a cortico-cortical evoked potential study.* **Brain Connectivity.** 10 (2017): 648-660.
11. **Keller CJ**, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. *Tuning face perception with electrical stimulation of the fusiform gyrus.* **Human Brain Mapping.** 6 (2017): 2830-2842.
12. **Keller CJ**, Chen C, Lado FA, Khodokakhah K. *The limited utility of high frequency activity in differentiating neuronal population dynamics in the mouse striatum.* **PLoS One.** 11 (2016): 1-20.
13. Entz L, Toth E, **Keller CJ**, Groppe DM, Megevand P, Fabo D, Ulbert I, Eross LG, Mehta AD. *The human neocortex demonstrates projectors and integrators of influence: a consideration in neuromodulation therapy.* **Neurosurgery.** 61 (2014): 1:224.
14. **Keller CJ**, Honey CJ, Entz L, Bickel S, Groppe DM, Toth E, Lado FA, Ulbert I, Mehta AD. *Probing the human connectome: cortico-cortical evoked potentials reveal projectors and integrators within human brain networks.* **Journal of Neuroscience.** 34 (2014): 9152-63.
15. Entz L, Toth E, **Keller CJ**, Bickel S, Groppe D, Fabo D, Kozak LR, Eross L, Ulbert I, Mehta AD. *Effective connectivity of the human neocortex derived from direct electrocortical stimulation.* **Human Brain Mapping.** 12 (2014): 5736-53.
16. Groppe DM, Bickel S, **Keller CJ**, Jain SK, Hwang ST, Harden C, Mehta AD. *Dominant frequencies of resting human brain activity as measured by the electrocorticogram.* **NeuroImage.** 79 (2013): 223-33.
17. Davidesco I, Zion-Golumbic E, **Keller CJ**, Bickel S, Harel M, Groppe DM, Schroeder C, Mehta AD, Malach R. *Exemplar selectivity reflects perceptual similarities in the human fusiform cortex.* **Cerebral Cortex.** 24 (2014): 1879-93.
18. **Keller CJ**, Bickel S, Honey CJ, Groppe DM, Craddock CR, Kelley C, Lado FA, Milham M, Mehta AD. *Neurophysiological investigation of spontaneous correlated and anticorrelated fluctuations of the BOLD signal.* **Journal of Neuroscience.** 33 (2013): 6333-42. **Impact: 7.2**
19. Dykstra A, Chan AM, Quinn BT, Zepeda R, **Keller CJ**, Cormier JE, Madsen JR, Eskandar EN, Cash SS. *Individualized localization and cortical surface-based registration of intracranial electrodes.* **NeuroImage** 59 (2012): 3563-70.
20. **Keller CJ**, Bickel S, Entz L, Ulbert I, Kelly C, Milham M, Mehta AD. *Intrinsic functional architecture predicts electrically-evoked responses in the human brain.* **Proceedings of the National Academy of Sciences** 108 (2011): 10308-13.
21. **Keller CJ**, Truccolo W, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle WK, Madsen JR, Schomer DL, Mehta AD, Brown EN, Hochbert LR, Ulbert I, Halgren E, Cash SS. *Distinct Neuronal Firing Types During Interictal Epileptiform Discharges in the Human Cortex.* **Brain** 133: (2010) 1668-81.
22. **Keller CJ**, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T,

Doyle W, Sassaroli A, Boas AD, Ulbert I, Halgren E. *Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex*. **Journal of Neuroscience Methods** 179 (2009) 208–218.

23. Gow DW, Jr, **Keller CJ**, Eskandar E, Meng N, Cash SS. *Superior temporal coordination of the perisylvian speech network: A Granger analysis of intracranial EEG data*. **Brain and Language**, 110 (2009) 43-8.

Peer-reviewed publications (in preparation / submitted – 10 total)

24. Wang JB, Bruss JE, Oya H, Uitermarkt BD, Trapp NT, Gander PE, Howard MA, **Keller CJ***, Boes AD*. *Effects of transcranial magnetic stimulation on the human brain recorded with intracranial electrocorticography: First-in-human study*. Submitted.
*Co-corresponding author; Last co-author with equal contributions
25. Ross JM[#], Sarkar M, **Keller CJ***. *Experimental suppression of TMS-EEG sensory potentials*. Submitted.
*Corresponding author
[#]Post-doctoral mentee
26. Hanjal B, Entz L, Toth E, **Keller CJ**, Wittner L, Mehta A, Ulbert I, Eross L, Fabo D. *Electrically evoked cortical potentials during wakefulness mirror slow oscillations during sleep*. Under review: *eNeuro*.
27. Xiao X, Bentzley BS, Cole EJ, Tischler C, Stimpson KH, Duvio D, Bishop JH, DeSouza DD, Schatzberg A, **Keller CJ**, Sudheimer KD, Williams NR. Functional connectivity changes with rapid remission from severe major depressive disorder. *Under Review: PNAS*.
28. Meshulam M, Golan T, Harel M, Groppe D, **Keller CJ**, Megevand P, Mehta A, Malach R. *Repeated performance in problem-solving tasks attenuates human cortical responses*. Under review: *Journal of Cognitive Neuroscience*.

Peer-reviewed publications (other – 4 total)

29. Wei CS, **Keller CJ**, Li J, Lin YP, Nakanishi M, Wagner J, Wu W, Zhang Y, Jung TP. *Editorial: Inter- and Intra-subject Variability in Brain Imaging and Decoding*. **Front Comput Neurosci**. 2021 Nov 29;15:791129.
Editorial
30. **Keller CJ***, Fischer AS*, Etkin A. *The clinical applicability of functional connectivity in depression: Pathways toward more targeted intervention*. **Journal of Biological Psychiatry: Cognitive Neuroscience and Neuroimaging**. 3 (2016): 262-270. *These authors contributed equally.
Review Paper
31. Belardinelli P, ... **Keller CJ**, ..., Ilmoniemi R. Reproducibility in TMS-EEG studies: a call for data sharing, standard procedures and effective experimental control. *Brain Stimulation*. 19 (2019): 30041-5.
Editorial

32. **Keller CJ**, Chen EC, Brodsky K, Yoon J. *A case of butane hash oil (marijuana wax)-induced psychosis. Substance Abuse.* 33 (2016): 384-386.
Case Report
33. Bott N, **Keller CJ**, Kuppuswamy M, Spelber D, Zeier J. *Cotard Delusion in the Context of Schizophrenia: A Case Report and Review of the Literature. Frontiers of psychology.* 2016 Sep 7;7:1351.
Case Report
34. **Keller CJ**, Honey CJ, Megevand P, Entz L, Ulbert I, Mehta AD. *Mapping complex brain networks with cortico-cortical evoked potentials. Phil Trans Royal Soc B.* 369 (2014): 1-14.
Review Paper

Non-Peer-reviewed Articles - Book Chapters (3 total)

1. Huang Y, **Keller CJ**. *How can I investigate causal brain networks with iEEG? In: Intracranial EEG for Cognitive Neuroscience.* 1st Edition, 2022.
2. **Keller CJ**, Bhati M, Downar J, Etkin A. *Brain Stimulation Therapies.* In: **The American Psychiatric Publishing Textbook of Psychiatry.** 6th Edition, 2018.
3. Wu, W, **Keller, CJ**, Etkin, A. *Artifact Rejection for Concurrent TMS-EEG Data.* In **Dynamic Neuroscience: Statistics, Modeling, and Control.** (eds. Chen, Z. & Sarma, S.V.) 141-173, Springer International Publishing, Cham, 2018.

Selected Abstracts (50 of 72)

1. **Keller CJ**, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A, McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Human Brain Mapping, Geneva, Switzerland, June 2016.
2. Mehta AD, Megevand P, Du V, Yeagle E, Herrero J, Mercier M, Bickel S, **Keller CJ**, Groppe DM, Entz L, Davis B, Argyelan M. Correspondence of BOLD- and Electrophysiology-Based Connectivity Dynamics Before and After Corpus Callosotomy. Human Brain Mapping, Geneva, Switzerland, June 2016.
3. **Keller CJ**, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A, McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Brain Stimulation and Imaging, Geneva, Switzerland, June 2016.
4. Du V, **Keller CJ**, Herrero J, Yeagle E, Khuvis S, Mehta AD. Modifying neural circuits with dual-site stimulation. Feinstein Institute for Biomedical Research Conference, Cold Spring Harbor Laboratory, New York, June 2016.
5. **Keller CJ**, Wu W, Wright R, Rolle C, Sarhadi K, Ichikawa N, Huemer J, Wong M, Yee A, McTeague L, Fini M, Du V, Honey CJ, Lado F, Mehta AD, Etkin A. Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales. Society of Biological Psychiatry, Atlanta, May, 2015

6. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Optimizing repetitive brain stimulation using direct electrical recordings from human brain networks. Society for Neuroscience, Chicago, IL, October, 2015.
7. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Induction and quantification of plasticity in human cortical networks using repetitive brain stimulation. Human Brain Mapping, Honolulu, HI, June, 2015.
8. **Keller CJ**, Fini M, Honey CJ, Lado FA, Mehta AD. Induction and quantification of plasticity in human cortical networks using repetitive brain stimulation. Society of Biological Psychiatry, Toronto, CA, May, 2015.
9. Entz L, Megevand P, Groppe DM, Toth E, Fabo D, Fallil Z, Hwang ST, Harden CL, Bickel S, **Keller CJ**, Mehta AD. Exploring seizure networks using cortico-cortical evoked potentials: internally hyperconnected, externally hypoconnected? American Epilepsy Society, Seattle, WA, December 2014.
10. **Keller CJ**, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. A causal role of the fusiform face area in face perception. Society for Neuroscience, Washington DC, November, 2014.
11. Groppe D, Megevand P, Bickel S, Mercier M, **Keller CJ**, Goldfinger MS, Mehta AD. Electrographic oscillatory activity predicts resting state functional magnetic resonance imaging connectivity. Society for Neuroscience, Washington DC, November, 2014.
12. Entz L, Toth E, Fabo D, **Keller CJ**, Bickel S, Eross L, Ulbert I, Mehta AD. Cortico-cortical evoked potentials may reveal pathological and function networks in the brain. Human Brain Mapping, Hamburg, Germany, June, 2014.
13. Groppe DM, Megevand P, Bickel S, **Keller CJ**, Goldfinger M, Mehta AD. Coherence vs fluctuations in high gamma band activity for defining resting state functional connectivity in the electrocorticogram. Human Brain Mapping, Hamburg, Germany, June, 2014.
14. **Keller CJ**, Davidesco I, Megevand P, Groppe DM, Lado FA, Mehta AD. A causal role of the fusiform face area in face perception. Human Brain Mapping, Hamburg, Germany, June, 2014.
15. Entz L, Toth E, **Keller CJ**, Groppe D, Megevand P, Fabo D, Ulbert I, Eross LG, Mehta AD. Evoked effective connectivity of the human neocortex and identification of seizure network properties. Cognitive Neuroscience, Boston, MA, April, 2014.
16. Megevand P, Goldfinger MS, Groppe DM, **Keller CJ**, Bickel S, Hwang ST, Fallil Z, Harden CL, Mehta AD. Safety of cortico-cortical evoked potentials by low-frequency stimulation of intracranial electrodes. American Epilepsy Society, Washington DC, December, 2013.
17. Groppe, D.M., Bickel, S., **Keller, CJ**, Kingsley, P.B., Mehta, A.D. (2013) Identification of eloquent cortical areas using resting state fMRI: A validation with in vivo direct cortical electrical stimulation in humans. Curing the Epilepsies 2013: Pathways Forward.
18. Groppe D, Entz L, Bickel S, **Keller CJ**, Megevand P, Mehta AD. Analysis of functional and effective brain networks using electrocorticography and corticocortical evoked potentials: correspondence with fMRI and beyond. Society for Neuroscience, San Diego, November, 2013.

19. **Keller CJ**, Groppe DM, Megevand P, Bickel S, Mehta AD. Electrophysiological Analysis of Default Mode Network Demonstrates Functional and Effective Connectivity. Society for Neuroscience, San Diego, November, 2013.
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21. Megevand P, Goldfinger M, Groppe DM, **Keller CJ**, Bickel S, Entz L, Mehta AD. Safety of cortico-cortical evoked potentials by low frequency stimulation of intracranial electrodes. American Epilepsy Society, Washington DC, 2013.
22. Toth E, Entz L, **Keller CJ**, Fabo D, Bickel S, Kozak LR, Eross L, Ulbert I, Mehta AD. Cortical electrical stimulation may reveal pathological and functional networks in the human brain. Hungarian Neuroscience Meeting, Budapest, Hungary, January 17-19, 2013.
23. Entz L, Toth E, **Keller CJ**, Bickel S, Fabo D, Kozak LR, Eross L, Ulbert I, Mehta AD. Anatomico-functional parcellation of the brain based on human electrical stimulation data. Hungarian Neuroscience Meeting, Budapest, Hungary, January 17-19, 2013.
24. **Keller CJ**, Entz L, Ahn S, Davidesco I, Groppe D, Bickel S, Toth E, Kingsley PB, Hwang S, Jain S, Ulbert I, Malach R, Lado F, Mehta AD. The electrophysiological signature of the default mode network. Human Brain Mapping, Seattle, Washington, June 13-17, 2013.
25. Golan T, Davidesco I, Groppe DM, Melloni L, Zion-Golumbic E, **Keller CJ**, Schroeder CE, Mehta A, Malach R. An ECoG exploration of the neural correlates of perceptual continuity during eye blinks. Human Brain Mapping, Seattle, Washington, June 13-17, 2013.
26. Entz L, **Keller CJ**, Toth E, Ulbert I, Eross L, Mehta AD. Electrical stimulation and functional MRI based multimodal approach to map functional and pathological brain areas. Society for British Neurological Surgeons, May 22-24, 2013.
27. Groppe D, Bickel S, **Keller CJ**, Jain S, Hwang S, Harden C, Mehta AD. Oscillations characteristic of non-epileptogenic neocortex in a resting state. American Epilepsy Society, San Diego, CA, November 29-December 4, 2012.
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29. Entz E, Toth E, **Keller CJ**, Bickel S, Groppe D, Ulbert I, Eross L, Mehta AD. Single Pulse Electrical Stimulation is a Promising Tool for Delineating the Seizure Focus Using Network Analysis. European Association of Neurological Societies, Bratislava, Slovakia, October 24-27, 2012.
30. Toth E, Entz L, Fabo D, **Keller CJ**, Bickel S, Kozak LR, Eross L, Ulbert I, Mehta AD. Pathological and functional network connectivity analysis in the human brain using single pulse electrical stimulation. *International Brain Research Organization*, Szeged, Hungary, Jan 19 - 21, 2012

31. Entz L, Bickel S, **Keller CJ**, Toth E, Eross L, Ulbert I, Mehta AD. Single Pulse Electrical Stimulation (SPES) is a Promising Tool for Localizing Functional and Pathological Networks. *American Association of Neurological Surgeons*, Miami, FL, April 14-18, 2012.
32. Jain S, Bickel S, Entz L, **Keller CJ**, Groppe D, Hwang S, Lado F, Mehta AD. Electrode localization in epilepsy surgery – developing a more accurate methodology. *American Epilepsy Society*, Baltimore, MD, December 4-8, 2011.
33. **Keller CJ**, Bickel S, Jain S, Groppe D, Entz L, Kelley C, Hwang S, Lado F, Mehta AD. Using correlated resting BOLD signal fluctuations to delineate seizure networks *American Epilepsy Society*, Baltimore, MD, December 4-8, 2011.
34. Groppe D, Bickel L, **Keller CJ**, Entz L, Mehta A. Dominant frequencies of human cortical areas as measured by electrocorticogram and direct stimulation of the cortical surface. *Society for Neuroscience*, Washington, DC, November 9-14, 2011.
35. Entz L, Bickel L, **Keller CJ**, Toth E, Ulbert I, Eross L, Mehta A. Resting state functional MRI and single pulse electrical stimulation (SPES) are possible new methods to map functional brain networks. *14th European Congress of Neurosurgery*, Rome, Italy, October 9-14, 2011. **Won best poster in stereotactic / functional section.**
36. Entz L, Bickel L, Toth E, **Keller CJ**, Vakili S, Corines J, Stream S, Sanjay J, Ulbert I, Mehta A. Identifying brain networks using single pulse electrical stimulation and resting state functional MRI connectivity analysis. *Congress of Neurological Surgeons*, Washington DC, October 1-6, 2011.
37. **Keller CJ**, Entz L, Bickel S, Honey CJ, Jain S, Groppe D, Hwang S, Lado F, Mehta AD. Probing the human connectome: Cortico-cortical evoked potentials reveal projectors and integrators within human brain networks. *Neuroinformatics*, Boston, MA, September 4-6, 2011.
38. Dykstra AD, Chan AM, Zepeda R, **Keller CJ**, Quinn BT, Cash SS. Individualized localization and cortical surface-based registration of semi-chronic intracranial electrodes. *Human Brain Mapping*, Quebec, CA, June 26-30, 2011.
39. Entz L, Bickel L, **Keller CJ**, Tóth E, Erőss L, Ulbert I, Mehta AD. Noninvasive Connectivity Analysis: A Novel Methodology for Functional Cortical Mapping. *The American Association of Neurological Surgeons Meeting*, Denver, CO, April 9-13, 2011.
40. Entz L, Bickel L, **Keller CJ**, Tóth E, Erőss L, Ulbert I, Mehta AD. Noninvasive Connectivity Analysis: A Novel Methodology for Functional Cortical Mapping. *The 13th Conference of the Hungarian Neuroscience Society*, Budapest, Hungary, January 20-22, 2011.
41. **Keller CJ**, Entz L, Bickel S, Hwang W, Jain S, Mehta AD. Identifying pathological and functional networks with single pulse electrical stimulation in patients with intractable epilepsy. *American Epilepsy Society*, San Antonio, TX, December 4-8, 2010.
42. Bickel S, Entz L, **Keller CJ**, Kelley C, Jain S, Hwang S, Mehta AD. Localization of epileptic and functional networks at rest using independent component and functional connectivity analysis of the BOLD signal. *American Epilepsy Society*, San Antonio, TX, December 4-8, 2010.

43. Bickel S, **Keller CJ**, Entz L, Kelley C, P. Kingsley, Jain S, Hwang S, Mehta AD. Probing language networks with electrical intracranial fMRI and resting state functional connectivity analysis. *Society for Neuroscience*, San Diego, CA, November 15-20, 2010.
44. **Keller CJ**, Bickel S, Entz L, Hwang S, Jain S, Mehta AD. Identifying pathological and functional networks with single pulse electrical stimulation and resting state functional MRI in patients with intractable epilepsy. *American Medical Association Research Symposium*, San Diego, CA, November 5-6, 2010.
45. Bickel S, Entz L, **Keller CJ**, Kelley C, P. Kingsley, Jain S, Hwang S, Mehta AD. Probing language networks with electrical intracranial fMRI and resting state functional connectivity analysis. *Cleveland Clinic Epilepsy Symposium*, Cleveland, OH, October 1-3, 2010.
46. Cash SS, **Keller CJ**, Ulbert I, Truccolo W, Cole AJ, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle W, Madsen JR, Schomer D, Mehta AD, Brown EN, Hochberg L and Halgren E. Successive Engagement of Different Cortical Circuits During Seizure Onset and Propagation. *American Clinical Neurophysiology Society*, San Diego, CA, February 2-7, 2010.
47. **Keller CJ**, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T, Doyle W, Sassaroli A, Boas DA, Ulbert I, Halgren E. Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex. *Society for Neuroscience*, Washington D.C., November 15-19, 2008.
48. Gow DW, Segawa J, and **Keller CJ**. Interactive processing in the identification of prosodic and segmental units in speech: Evidence from multimodal imaging and Granger analysis. *International Conference on Cognitive and Neural Systems*, Boston, MA, May 14-17, 2008.
49. Weiner V, Cash SS, Eskandar E, **Keller CJ**, Peterfreund RA, Pierce ET, Salazar AF, Szabo MD, Brown EN, Purdon PL. Intracranial neural recordings in deep structures of the human brain during general anesthesia; implications for improved anesthetic monitoring. *MGH Clinical Research Symposium*, May 28, 2009.

----- BELOW NOT TO BE INCLUDED IN SUBMISSION-----

Professional Training

- 2018 NIH Brain Camp, Cold Spring Harbor Laboratory, NY
- 2018 Career Development Institute, Pittsburgh, PA
- 2017 TMS-EEG Workshop, Helsinki, Finland
- 2016 Combining Brain Stimulation and Neuroimaging Short Course, Geneva, Switzerland
- 2014 NINDS Combining Clinical and Research Careers in Neuroscience, Washington, DC
- 2014 Human Brain Mapping Short Course, Brain Stimulation, Hamburg, Germany
- 2013 Society for Neuroscience Short Course, Advances in ECoG, New Orleans, LA
- 2013 Neural Systems and Behavior, Marine Biology Laboratory, Woods Hole, MA

Non-invited Presentations

International

- 17. **Keller, CJ (2022).** *Modifying human neural circuits with precision neurotherapeutics.* International Federation of Clinical Electrophysiology. Geneva, Switzerland.
- 18. **Keller, CJ (2017).** *Naturalistic clinical monitoring of rTMS-induced plasticity with TMS-EEG.* TMS-EEG Workshop, Helsinki, Finland.
- 19. **Keller, CJ (2017).** *Naturalistic clinical monitoring of rTMS-induced plasticity with TMS-EEG.* Winter Brain Conference, Vancouver, BC.
- 20. **Keller, CJ (2017).** *Towards personalized rTMS treatment for MDD.* Human Brain Mapping, Vancouver, BC.
- 21. **Keller, CJ (2016).** *Repetitive brain stimulation induces long-term plasticity across patient populations and spatial scales.* Brain Stimulation Conference, Human Brain Mapping, Geneva, Switzerland.
- 22. **Keller, CJ (2014).** *The neural origins of resting functional brain networks.* Human Brain Mapping, Hamburg, Germany.

National

- 23. Keller, CJ (2021). *Combining TMS and intracranial EEG to probe human cortical networks.* International Brain Stimulation Conference. Charleston, South Carolina.
- 24. Keller, CJ (2019). *Towards Personalized Brain Stimulation for Neuropsychiatric Disorders.* Society for Biological Psychiatry, Chicago, IL.
- 25. Keller, CJ (2018). *Large-scale, naturalistic rTMS plasticity monitoring.* University of Texas Southwestern, Dallas, TX.
- 26. Keller, CJ (2018). *Personalized Medicine for Subjects with Treatment-Resistant Major Depressive Disorder: Novel Strategies to Optimize Treatment with Antidepressant Medications, rTMS, Ketamine, and ECT.* Anxiety and Depression Association of America, Washington, DC.

27. Keller, CJ (2016). *Simultaneous TMS-EEG as a causal tool to probe functional brain networks*. Winter Brain Conference, Big Sky, Montana.

Regional

28. Keller, CJ (2017). *Induction and quantification of brain plasticity across populations and scales*. Society for Biological Psychiatry, San Diego, CA.

RESEARCH STATEMENT

My work maps the interaction between brain networks, stimulation-induced brain changes, and neuropsychiatric symptoms. I combine my backgrounds in electrophysiology, bioengineering, and neuroscience to perform translational research while practicing as an interventional psychiatrist, with a focus on mood disorders and treatment-resistant depression. During my PhD, I developed novel intracranial brain mapping tools and applied these to demonstrate the neural basis of resting functional MRI in humans. During residency and my postdoctoral fellowship, I co-developed fully automated non-invasive brain mapping techniques, now used across industry and academia. My laboratory combines techniques from computer science, neuroscience, and engineering coupled with a clinical understanding of psychiatry to focus on three central aims: 1) to better understand the mechanisms underlying human brain plasticity; 2) to develop novel methods to probe the human brain; and 3) to personalize brain stimulation by developing trans-diagnostic platforms for rapid biomarker development, evaluation, and integration into brain stimulation treatments. This approach has the expected outcome of producing novel stimulation treatments with enhanced specificity, plasticity, and efficacy. By increasing our mechanistic understanding and ability to monitor brain changes during stimulation, we will markedly increase the utility of these powerful techniques. Together, this work will help transform interventional psychiatry from a one-size-fits-all treatment approach to one that focuses on targeting objective biomarkers for the individual, pushing the field towards personalized neurotherapeutics.

Personal Statement

My work maps the interaction between brain networks, stimulation-induced brain changes, and neuropsychiatric symptoms. I combine my backgrounds in electrophysiology, bioengineering, and neuroscience to perform translational research while practicing as an interventional psychiatrist, with a focus on mood disorders and treatment-resistant depression. The mission of my lab is to deconstruct brain stimulation to identify the fundamental building blocks of neuroplasticity and use these principles to build personalized treatments for mental health disorders. All types of brain stimulation – but especially non-invasive brain stimulation such as TMS – is vastly underutilized. In TMS, for example, treatment is applied in just one of two patterns ('10Hz' or 'iTBS') – utilizing a very small fraction (<1%) of potential stimulation patterns available. Furthermore, these TMS patterns are applied in an *open-loop* fashion, critically with no monitoring of brain changes during treatment (and thus no updating of treatment based on brain changes). My laboratory was created to change this status quo that has existed for 15+ years. We have set out to develop a novel and more effective form of TMS; one that is based on an individual's brain circuitry, tracks neuroplasticity in the clinic in *real-time*, and utilizes the vast multidimensional stimulation parameter space to continuously update treatment accordingly in *closed-loop* fashion. This work importantly not only considers one's underlying brain circuitry but the *moment-to-moment* excitability and plasticity of the circuit, which changes during treatment and of which TMS patterns are sensitive to. This ambitious endeavor requires developing and refining a brain biomarker, exploring the multidimensional stimulation parameter space, and building real-time, closed-loop treatment platforms.

For this work to be feasible and mechanistically grounded, we first developed and refined *causal and directional* brain connectivity metrics in humans. In epilepsy patients, I helped develop one of the first methods in awake humans to map causal connectivity – cortico-cortical evoked potential (CCEP)

mapping. Here, a current injection in one region directly on the cortical surface elicits brain responses in functionally connected regions. This work resulted in five first author publications (PNAS, Journal of Neuroscience, Brain). Currently CCEP mapping is used at nearly every hospital with epilepsy surgery. We used CCEP mapping to demonstrate that repetitive intracranial electrical stimulation, patterned to mimic TMS (at 10Hz), modulated prefrontal circuits for 15-30 minutes in a predictable manner based.

While encouraging, to apply a CCEP-like causal connectivity approach in outpatient clinics, however, this tool had to be translated non-invasively. We coupled concurrent transcranial magnetic stimulation (TMS) with scalp EEG recordings and developed the first fully automated TMS-EEG analytic pipeline, allowing standardization and high throughput. We used this TMS-EEG analytic pipeline in a randomized, double-blind, placebo-controlled clinical trial (NCT01829165) to investigate the neural underpinnings of clinical effects of TMS treatment for depression. We demonstrated TMS treatment modulates fronto-parietal brain excitability and the degree of modulation after TMS importantly predicted over 50% of clinical outcome. This work suggests that specific *depression severity biomarkers* like this TMS-EEG marker may be used to predict non-responders, monitor brain networks during intervention, and be used to propose novel targets and treatment paradigms. We next scaled this brain biomarker monitoring approach to 10 outpatient TMS centers. This work formed the basis for Alto Neuroscience.

With this brain biomarker in hand, we recently set out to explore the extensive and unmapped TMS stimulation parameter space. We are mapping how different stimulation frequencies, patterns, duration, power, and location acutely modulate brain activity and cognition to develop a library of brain responses for closed-loop algorithms. In parallel we have developed a software platform that localizes and cleans these brain biomarkers in real-time. Finally, we are testing different closed-loop algorithms to determine how they differentially modulate the speed and specificity of change in our brain biomarkers. Taken together, by more thoroughly mapping the stimulation parameter space, enabling real-time monitoring, and demonstrating proof of concept closed-loop TMS treatment, we will help propel TMS from a one-size-fits-all treatment approach without individualization or brain monitoring to one that targets objective biomarkers to enhance neuroplasticity and clinical outcome, pushing the field towards personalized neurotherapeutics. Importantly, this platform is broadly applicable to other depression biomarkers, all psychiatric populations treated with TMS, and other brain stimulation modalities (e.g. vagus nerve stimulation, deep brain stimulation).

Contribution to Science

1. My early work in the laboratory of Sydney Cash focused on the mechanisms underlying inter-ictal spikes, which define epileptic cortex. We recorded simultaneous local field potentials and single neuron action potentials during inter-ictal discharges (IID) using high density microelectrode arrays implanted in patients with medically-resistant epilepsy to characterize the firing pattern that underlies IIDs. We determined that only $\frac{1}{2}$ of neurons in epileptic areas modulate their firing rate during IIDs. Furthermore, as expected $\frac{1}{4}$ of neurons increased their firing rate during the IID. In direct contrast to predictive models of the IID, however, we identified a subset of population of neurons that modulate their firing rate *prior* to the IID. These subset of neurons were only observed in epileptic regions, suggesting they may play a role in the generation of the IID. During this time, we also developed a microelectrode that records simultaneous electrophysiology and hemodynamics and an algorithm for accurately localizing intracranial electrodes implanted in patients during epilepsy surgery.
 - a. **Keller CJ**, Cash SS, Narayanan S, Wang C, Kuzniecky R, Carlson C, Devinsky O, Thesen T, Doyle W, Sassaroli A, Boas AD, Ulbert I, Halgren E. *Intracranial microprobe for evaluating neuro-hemodynamic coupling in unanesthetized human neocortex*. Journal of Neuroscience Methods 179 (2009) 208–218.
 - b. Dykstra A, Chan AM, Quinn BT, Zepeda R, **Keller CJ**, Cormier JE, Madsen JR, Eskandar EN, Cash SS. *Individualized localization and cortical surface-based*

- registration of intracranial electrodes*. *NeuroImage* 59 (2012): 3563-70.
- c. **Keller CJ**, Truccolo W, Gale JT, Eskandar E, Thesen T, Carlson C, Devinsky O, Kuzniecky R, Doyle WK, Madsen JR, Schomer DL, Mehta AD, Brown EN, Hochbert LR, Ulbert I, Halgren E, Cash SS. *Distinct Neuronal Firing Types During Interictal Epileptiform Discharges in the Human Cortex*. *Brain* 133 (2010) 1668-81.
2. During my PhD with Ashesh Mehta, Fred Lado, and Michael Milham, with a team of interdisciplinary collaborators, we documented the relationship between fMRI and underlying physiology. fMRI is now in mainstream use, but the neurophysiology of positive and negatively correlated BOLD fluctuations – which consistently identify large scale networks implicated in cognitive, sensory, and motor functions, and which differentiate patients from healthy subjects in many neuropsychiatric diseases – is largely unknown and confounded by multiple artifacts that exist in these recordings. I directly demonstrated that the spatial distribution and magnitude of temporally correlated low-frequency BOLD fluctuations (‘resting fMRI’) predict the pattern and magnitude of evoked potentials measured intracranially following focal electrical stimulation. These findings were replicated across patients and functional subsystems and strengthened the notion that resting fMRI signals are grounded in neurophysiology. We furthermore demonstrated that positively and negatively correlated fluctuations of high gamma activity underlie positive and negative BOLD correlations, respectively, suggesting that both resting BOLD interactions have neurophysiological origins in slow power modulations of fast frequency activity. This work has driven >20 groups across the world to begin collecting cortico-cortical evoked potentials (CCEPs), where a causal electrical disturbance in the brain elicits brief changes in neuronal excitability that can be measured in the local field potential.
- a. **Keller CJ**, Bickel S, Entz L, Ulbert I, Kelly C, Milham M, Mehta AD. *Intrinsic functional architecture predicts electrically-evoked responses in the human brain*. **Proceedings of the National Academy of Sciences** 108 (2011): 10308-13.
 - b. **Keller CJ**, Bickel S, Honey CJ, Groppe DM, Craddock CR, Kelley C, Lado FA, Milham M, Mehta AD. *Neurophysiological investigation of spontaneous correlated and anticorrelated fluctuations of the BOLD signal*. **Journal of Neuroscience**. 33 (2013): 6333-42.
 - c. **Keller CJ**, Honey CJ, Entz L, Bickel S, Groppe DM, Toth E, Lado FA, Ulbert I, Mehta AD. *Probing the human connectome: cortico-cortical evoked potentials reveal projectors and integrators within human brain networks*. **Journal of Neuroscience**. 34 (2014): 9152-63.
 - d. **Keller CJ**, Honey CJ, Megevand P, Entz L, Ulbert I, Mehta AD. *Mapping complex brain networks with cortico-cortical evoked potentials*. **Philosophical Transactions of the Royal Society B: Biological Sciences**. 1 (2014): 369 (1653).
3. As a post-doctoral fellow with Amit Etkin, I co-developed a fully automated analytic pipeline for analysis of concurrent transcranial magnetic stimulation (TMS) coupled with EEG. This toolbox is currently being used across 10 different projects examining plasticity abnormalities in multiple patient populations. We also performed a randomized, double-blind, placebo-controlled clinical trial to investigate the electrophysiological underpinnings of clinical effects of daily repetitive TMS (rTMS) treatment for depression. We utilized the toolbox developed to show that rTMS treatment modulates TMS-evoked potentials and the strength of modulation predicts clinical outcome. This work suggests that specific TMS-EEG brain-based biomarkers may be used to predict non-responders, monitor brain networks during intervention, and be used to propose novel targets and treatment paradigms.
- a. **Keller CJ***, Wu W*, Rogasch NC, Longwell P, Spigel E, Rolle CE, Etkin A. *ARTIST: A*

- Fully Automated Artifact Rejection Algorithm for Single-Pulse TMS-EEG Data. **Human Brain Mapping.** 00 (2018): 1-19. *These authors contributed equally.*
- b. **Keller CJ***, Kerwin L*, Wu W, Etkin A. *Test-Retest Reliability of Transcranial Magnetic Stimulation EEG Evoked Potentials. **Brain Stimulation:** 3 (2018): 536-44. *These authors contributed equally.*
- c. **Keller CJ***, Fischer AS*, Etkin A. *The clinical applicability of functional connectivity in depression: Pathways toward more targeted intervention. **Journal of Biological Psychiatry: Cognitive Neuroscience and Neuroimaging.** 3 (2016): 262-270. *These authors contributed equally.*
- d. **Keller CJ**, Huang D, Honey CJ, Du V, Fini M, Lado FA, Mehta AD. *Induction and quantification of excitability changes in human cortical networks. **Journal of Neuroscience:** 23 (2018): 5384-98.*
- e. Huang D, Herrero J, Entz L, Fabo D, Hajnal B, Mehta A, **Keller CJ.** *Intracortical dynamics underlying repetitive stimulation predicts changes in network connectivity. **Journal of Neuroscience:** 31 (2019): 6122-6135.*

Thesis Work

PhD Dissertation: *Investigating the neurophysiological origins of spontaneous fluctuations of the BOLD signal, high frequency oscillations, and the default mode network.*

Dept of Neuroscience, Albert Einstein College of Medicine
 07/2011 – 10-2013 ; High Honors
 Mentors: Drs Fred Lado and Ashesh Mehta
 Advisory Committee: Adam Kohn, Kamran Khodokakhah,
 Joseph Arezzo, Charles Schroeder

Master's Thesis: *Seeking the Neuro-Hemodynamic Basis of Epilepsy: Evidence from Human Intracranial EEG, Laser Doppler Flowmetry, Cortical Point Spectroscopy, and Single Unit Activity*

Dept of Biomedical Engineering, Tufts University
 09/2007 – 05-2009; Highest Honors
 Mentors: Sergio Fantini (Tufts); Sydney Cash (Harvard)