Oren Shriki, PhD Apr. 2020

CURRICULUM VITAE

Personal Details

Name: Oren Shriki
Address and telephone number at work:
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Dept. of Computer Science
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Education

B.Sc. - 1991-1994, Hebrew University, Physics (Graduated *magna cum laude*)
Ph.D. - 1994-2003, Hebrew University, Interdisciplinary Center for Neural Computation
Name of advisor: Prof. Haim Sompolinsky
Title of thesis: Dynamic and Computational Models of Recurrent Networks in the Brain.

Employment History

Oct. 2017 – present, Senior lecturer, Computational Psychiatry Lab, Dept. of Cognitive and Brain Sciences and Dept. of Computer Science, Ben-Gurion University, Be'er-Sheva,
Oct. 2013-Sep. 2017, Lecturer, Computational Psychiatry Lab, Dept. of Cognitive and Brain Sciences and Dept. of Computer Science, Ben-Gurion University, Be'er-Sheva, Israel
2010–2013, Postdoctoral fellow, National Institutes of Mental Health (Bethesda MD, USA)
2009–2010, Postdoctoral fellow, Ben-Gurion University
2000-2009, High school physics teacher, Israeli Arts and Sciences Academy (Jerusalem, Israel). Established a brain research and robotics laboratory. Supervised numerous projects, many of which won national and international prizes.

Acronyms for academic institutes used in the subsequent pages:
BGU - Ben-Gurion University, HUJI – Hebrew University Jerusalem Israel, WIS – Weizmann Institute of Science, BIU – Bar-Ilan University, TAU – Tel-Aviv University.

Professional Activities

(a) Positions in academic administration
2014-2016, Dept. of Cognitive and Brain Sciences, BGU, Counselor for 1st year undergrad students
2014-2019, Dept. of Cognitive and Brain Sciences, BGU, Counselor for MA students
2014-present, Dept. of Cognitive and Brain Sciences, BGU, Counselor of the computational track in the undergraduate program

(b) Professional functions outside universities/institutions

(c) Significant professional consulting
EEG-SENSE, Petach-Tikva, consultant, EEG signal processing

(d) Editor or member of editorial board of scientific or professional journal

(e) Ad-hoc reviewer for journals

PLoS Biology, eLife, Journal of Neuroscience, Neuroimage, Scientific Reports, PLoS ONE, Journal of Neurophysiology, Chaos, Entropy, Journal of Computational Neuroscience, Journal of Statistical Physics, Frontiers Journals, IEEE Transactions on Neural Systems & Rehabilitation Engineering.

(f) Membership in professional/scientific societies
2010-present, Society for Neuroscience
2013-present, Israeli Society for Neuroscience
2016-present, Brain-Computer Interface Society
2019-present, Aerospace Medical Association

Educational activities

(a) Courses taught

Present:

- Computation and cognition, graduate, BGU
- Workshop in MATLAB and analysis of data from neural systems, undergrad, BGU
- Introduction to computation and cognition, undergrad, BGU
- Brain-Computer Interfaces, graduate, BGU

Past:

- Linear systems and their application in neuroscience, graduate, WIS
- Dynamical systems in neuroscience, graduate, WIS
- Basic models in theoretical neuroscience, graduate, WIS
- Introduction to brain sciences and neural computation, undergraduate, HUJI
- Theoretical neuroscience, graduate, BIU

Awards, Citations, Honors, Fellowships

(a) Honors, Citation Awards

2019 Desert Nova (Competitive internal grant at BGU).
"NeuroFalcon - Neurotechnology for Monitoring the Pilot Brain" ($36000).
2018 Interdisciplinary Research Grant (Competitive internal grant at BGU) ($8500).
"Towards a Time-warping Invariant Deep-learning Based Prediction of Epileptic Seizures".
With Dr. Oren Freifeld.
2017 "My teacher – teacher for life" award, Technion.
2015 Paedagogica Foundation of Switzerland, 2015 Recipient
Recruitment and Retention Award for Outstanding New Scientists ($100,000)
2014 Internal grant of the ABC robotics initiative, BGU.
"Seamless Human-Robot Interaction".
With Prof. Tal Oron-Gilad, Dr. Idit Shalev and Prof. Jihad El-Sana.
2014 Internal grant of the ABC robotics initiative, BGU.
"Co-Adaptive Learning of Brain-Computer Interfaces".
With Dr. Lior Shmuelof.
2003 Excellent teacher award, HUJI.
2002 Excellent teacher award, HUJI.
1999 Yaglom prize for physics students, HUJI.
1994 Intel-Dean's prize, HUJI.
1993 Dean's Prize, HUJI.
1992 Dean's List, HUJI.

(b) Fellowships

2010-2013 National Institute of Mental Health (US), ~$67000 per year, Postdoc

2006 National Institute for Psychobiology in Israel, ~$25000, Postdoc
2004 National Institute for Psychobiology in Israel, ~$25000, Postdoc
2003 Feinberg Graduate School at WIS, ~$25000, Postdoc
1993 Summer course scholarship for undergraduate physics students at WIS.
1993 Ben-Gurion Scholarship of the Israeli Ministry of Science.

Scientific Publications

H-index and citations:
ISI: 11, Total number of citations: 492, minus self (-43): 449.
Google Scholar (GS): 14, Total number of citations: 869, minus self (-43): 826.

(a) Authored books

(b) Editorship of collective volumes

(c) Refereed chapters in collective volumes, Conference proceedings, Festschrifts, etc.

1. **Shriki O.**[S], Sompolinsky H. [PI] and Lee D.D.[C], 2001, An Information-Maximization Approach to overcomplete and Recurrent Representations, *Advances in Neural Information Processing Systems* 13: 612-618. (Conference rank: A*; Presented as a talk with an acceptance ratio of 1/25; Citations- ISI: 7, GS: 28).
2. Lerner I.[S], Bentin S.[C], and **Shriki O.**[PI], 2010, Automatic and Controlled Processes in Semantic Priming: an Attractor Neural Network Model with Latching Dynamics, *CogSci*, 2010 (Citations- ISI: 2, GS: 7).
3. **Shriki O.** [PD], and Plenz D. [PI], 2014, Neuronal Avalanches in the Human Brain, book chapter in *Criticality in Neural Systems*, Eds. Plenz D., Niebur E., Schuster H. G. (Wiley Press; Citations- ISI: 1, GS: 2).
4. Yu S. [PD], Yang H. [S], **Shriki O.** [PD], and Plenz D. [PI], 2014, Critical Exponents, Universality Class & Thermodynamics: The "Temperature" of the Brain, book chapter in *Criticality in Neural Systems*, Eds. Plenz D., Niebur E., Schuster H. G. (Wiley Press; Citations- ISI: 1, GS: 2).
5. Chatterjee S.[S], Shriki O.[C], Shalev I.[C], and Oron-Gilad T.[PI], 2016, Postures of a Robot Arm - Window to Robot Intentions? *RO-MAN 2016, 25th IEEE International Symposium on Robot and Human Interactive Communication*.
6. * Dotan A. [S] and **Shriki O.** [PI], An Entropy Maximization Approach to Optimal Dimensionality Reduction, 2018, *International Joint Conference on Neural Networks (IJCNN), IEEE*, 2018. (Conference rank: A).
7. * Rapaport E. [S], **Shriki O.** [PI] and Puzis R. [PI], EEGNAS: Neural Architecture Search for Electroencephalography Data Analysis and Decoding, *IJCAI-HBAI* 2019. (Conference rank: A; Citations- ISI: 0, GS: 1).
8. * Serota B.[S], Golan Y. [S], Shapiro A. [C], **Shriki O.** [C] and Nisky I. [PI], A Vibrotactile Vest for Remote Human-Dog Communication, 2019 *World Haptics Conference*. (Conference rank: B1).
9. * Shapira-Weber R. [S], Eyal M. [S], Skafte Detlefsen N. [S], **Shriki O.** [PI] and Freifeld O.[PI], 2019, Diffeomorphic Temporal Alignment Nets, *Advances in Neural Information Processing Systems* 33: 6570-6581. (Conference rank: A*).
10. * Zakkay E. [S], Abu-Rmileh A.[PD], Geva A. B.[C] and **Shriki O.**[PI], Real-time asynchronous brain-computer interfaces using echo state networks, 2020, *International Joint Conference on Neural Networks (IJCNN), IEEE*, 2020. (Conference rank: A).

(d) Refereed articles and refereed letters in scientific journals

1. **Shriki O.**[S], Sompolinsky H. [PI] and Hansel D. [PI], 2003, Rate Models for Conductance-Based Cortical Neuronal Networks, *Neural Computation* **15**: 1809-1841. (IF: 2.406; Q2 Computer Science, Artificial Intelligence; 66/134; Citations- ISI: 125, GS: 231)
2. **Shriki O.** [PD] *****, Kohn A. [C] and Shamir M. [PI], 2012, Fast Coding of Orientation in Primary Visual Cortex, *PLoS Computational Biology* 8(6): e1002536. doi:10.1371 / journal.pcbi.1002536. (IF: 5.042; Q1 Mathematical & Computational Biology; 5/59; Citations- ISI: 17, GS: 29)
3. Lerner I.[S], Bentin S.[C] and **Shriki O.** [PI] *,2012, Excessive Attractor Instability Accounts for Semantic Priming in Schizophrenia, *PLoS ONE* 7(7): e40663. doi:10.1371 / journal.pone.0040663. (IF 3.337; Q2 Multidisciplinary Sciences; 24/69; Citations- ISI: 14, GS: 25).
4. Lerner I.[S], Bentin S.[C], and **Shriki O.**[PI]*****, 2012, Spreading Activation in an Attractor Network With Latching Dynamics: Automatic Semantic Priming Revisited, *Cognitive Science* **36**: 1339-1382. (IF 2.863; Q2 Experimental Psychology; 37/88; Citations- ISI: 19, GS: 38).
5. **Shriki O.**[PD]*****, Alstott J.[S], Carver F. [C], Holroyd T. [C], Henson R. [C], Smith M. L. [C], Coppola R. [C], Bullmore E. [C], and Plenz D. [PI], 2013, Neuronal Avalanches in the Resting MEG of the Human Brain, *Journal of Neuroscience* **33**: 7079-7090. (IF: 7.115; Q1 Neurosciences; 9/312; Citations- ISI: 112, GS: 169).
6. Yu S. [PD], Yang H. [S], **Shriki O.** [PD], and Plenz D. [PI], 2013, Universal Organization of Resting Brain Activity at the Thermodynamic Critical Point, *Frontiers in Systems neuroscience*. (IF 6.040; Q1 Neurosciences; 22/312; Citations- ISI: 38, GS: 42).
7. Meisel C.[PD], Olbrich E.[C], **Shriki O.** [PD], and Achermann P. [PI], 2013, Fading signatures of critical brain dynamics during sustained wakefulness in humans. *Journal of Neuroscience*, 33: 17363-17372. (IF: 7.115; Q1 Neurosciences; 9/312; Citations- ISI: 51, GS: 76).
8. Lerner I.[S], Bentin S.[C], and **Shriki O.**[PI], 2014, Integrating the Automatic and the Controlled: Strategies in Semantic Priming in an Attractor Network with Latching Dynamics. *Cognitive Science* 38. (IF 2.863; Q2 Experimental Psychology; 37/88; Citations- ISI: 4, GS: 6).
9. Lerner I. [S], and **Shriki O.** [PI], 2014, Internally- and Externally-Driven Network Transitions as a Basis for Automatic and Strategic Processes in Semantic Priming: Theory and Experimental Validation. *Frontiers in Psychology*, doi: 10.3389/fpsyg.2014.00314. (IF: 2.871; Q2 Multidisciplinary Psychology; 40/137; Citations- ISI: 12, GS: 19).
10. Arviv O. [S], Goldstein A.[PI], and **Shriki O.** [PI], 2015, Near-critical dynamics in stimulus-evoked activity of the human brain and its relation to spontaneous resting-state activity. *Journal of Neuroscience*, 35: 13927–13942. (IF: 7.115; Q1 Neurosciences; 9/312; Citations- ISI: 21, GS: 33).
11. **Shriki O.** **[PI]**, Yellin D.[S], 2016, Optimal Information Representation and Criticality in an Adaptive Sensory Recurrent Neural Network. *PLoS Computational Biology* 12(2): e1004698. doi:10.1371/journal.pcbi.1004698. (Q1 Mathematical & Computational Biology; 5/59; Citations- ISI: 17, GS: 20).
12. **Shriki O**. [PI], Sadeh Y.[S] and Ward J. [PI], 2016, The Emergence of Synaesthesia in a Neuronal Network Model via Changes in Perceptual Sensitivity and Plasticity. *PLoS Computational Biology* 12(7): e1004959. doi:10.1371/journal.pcbi.1004959. (IF: 5.042; Q1 Mathematical & Computational Biology; 5/59; Citations- ISI: 6, GS: 12).
13. Arviv O.[S], Medvedovsky M.[C], Sheintuch L.[S] , Goldstein A.[C], and **Shriki O.** [PI], 2016, Deviations from critical dynamics in inter-ictal epileptiform activity. *Journal of*

Neuroscience, 36: 12276-12292 (IF: 7.115; Q1 Neurosciences; 9/312; Citations- ISI: 6, GS: 8).

14. * Alkoby O.[S], Abu-Rmileh A.[PD], **Shriki O.*** [PI], and Todder D. [PI], 2018, Can we predict who will respond to Neurofeedback? A review of the inefficacy problem and existing predictors for successful EEG Neurofeedback learning. *Neuroscience* 378: 155-164 (IF: 3.504; Q2 Neurosciences; 114/267; Citations- ISI: 17, GS: 46).
15. * Priesemann V. [PI] and **Shriki O.** [PI], 2018, Can a time varying external drive give rise to apparent criticality in neural systems? *PLoS Computational Biology* 14(5): e1006081. (IF: 5.042; Q1 Mathematical & Computational Biology; 5/59; Citations- ISI: 8, GS: 16)
16. * Fekete T.[PD], Omer D.[PD], Kazunori O.[PD], Grinvald A. [C], van Leeuwen C.[C], and **Shriki O.**[PI], 2018, Critical dynamics, anesthesia and information integration: lessons from multiscale criticality analysis of voltage imaging data. *Neuroimage*, 183: 919-933 (IF: 6.918; Q1 Neuroimaging; 1/14; Citations- ISI: 5, GS: 11).
17. * Artzi N.[S], and **Shriki O.**[PI], 2018, An Analysis of the Accuracy of the P300 BCI Brain-Computer Interface. *Brain-Computer Interfaces*. doi: 10.1080/2326263X.2018.1552357. (Journal citation information not available; Citations- ISI: 0, GS: 0).
18. * Friedman N.[S], Fekete T.[PD]., Gal K.[PI] and **Shriki O.**[PI], 2019, EEG-based Prediction of Cognitive Load in Intelligence Tests, *Frontiers in Human Neuroscience*. (IF: 3.964; Q2 Psychology; 21/77; Citations- ISI: 0, GS: 3).
19. * Gordon S. [S], Todder D. [C], Duetsch I. [S], Garbi D. [S], Alkobi O. [S], **Shriki O.** [C], Shkedy-Rabani A.[S], Shahar N. [S] and Meiran N. [PI], 2019, Effects of Neurofeedback and Working Memory Combined Training on Executive Functions in Healthy Young Adults. *Psychological Research*. (IF: 2.980; Q1 Experimental Psychology; 22/88; Citations- ISI: 0, GS: 0).
20. * Arviv O. [PD], Goldstein A.[C], and **Shriki O.**[PI], 2019, Neuronal avalanches and time-frequency representations in stimulus-evoked activity, *Scientific Reports*. (IF: 4.525; Q1 Multidisciplinary Studies; 15/69; Citations- ISI: 0, GS: 0).
21. * Abu-Rmileh A.[PD], Zakkay E. [S], Shmuelof L. [†PI] and **Shriki O.** [†PI], 2019, Co-adaptive learning improves performance in a multi-day EEG-based motor imagery BCI training. *Frontiers in Human Neuroscience*. (IF: 3.964; Q2 Psychology; 21/77; Citations- ISI: 0, GS: 0) ([†] - equal contribution).
22. * Levi-Aharony H. [S], **Shriki O.** [†PI] and Tishby N. [†PI], 2019, Surprise Response as a Probe for Compressed Memory States. *PLoS Computational Biology*. (IF: 5.042; Q1 Mathematical & Computational Biology; 5/59; Citations- ISI: 0, GS: 1) ([†] - equal contribution).

Lectures and Presentations at Meetings and Invited Seminars

(a) Invited plenary lectures at conferences/meetings

2019, Critical Brain Dynamics: A Novel Framework for Assessing and Regulating Brain Dynamics, Keynote speaker, International Society for Neurofeedback and Research, Denver, CO, USA

2019, Critical brain dynamics and applications to sleep deprivation, anesthesia and disorders of consciousness, *Israel Society for Neuroscience*, Eilat, Israel

2018, From Theory to Practice: How Ideas in Computational Neuroscience can be Translated into Neurotechnology, *The 2nd Japan-Israel Brain Sciences Symposium*, Tokyo, Japan

2018, Co-Adaptive Learning Improves Efficacy of Multi-Day EEG-based Motor Imagery BCI Training, *The Seventh International BCI Meeting*, Asilomar, CA, USA.

2018, Dynamical implications of optimal temporal information encoding in recurrent networks of spiking neurons, *Bernstein Conference on Computational Neuroscience*, Berlin, Germany.

2017, Critical Brain Dynamics: A Novel Framework for Assessing and Optimizing Brain Function, *Cognitive Improvement*: *Approaches, Mechanisms and Applications*, BIU, Israel.

2017, On Optimal Information Representation and Criticality, *Dynamical network states, criticality and cortical function*, Institute for Advanced Studies, Bremen, Germany.

2016, Criticality in Stimulus-Evoked Activity of the Human Brain, *Critical Brain Dynamics*, NIH, Bethesda, MD, USA.

2015, Critical dynamics in resting and evoked human brain activity, *NeuroBridges*, Paris, France.

2015, How Sensory Deprivation and High Plasticity may lead to Hallucinations and Synaesthesia: An information theoretic perspective, *Information and the Cognitive Sciences*, Jerusalem, Israel.

2014, Information Maximization and Criticality in Recurrent Neural Networks: Theory and Applications, *5th ELSC Workshop in Theoretical Neuroscience*, Jerusalem, Israel.

2014, Optimal Information Representation and Criticality in Recurrent Neural Networks, *German-Israeli Minerva School on Cognitive Robotics*, Berlin, Germany.

2014, Monitoring the balance of excitation and inhibition in the human brain using neuronal avalanches, *France-Israel Binational Neuroscience Conference*, Sde-Boker, Israel.

2011, Signatures of Criticality in Human Brain Dynamics, *SIAM Conference on Applications of Dynamical Systems*, Snowbird, Utah.

(b) <u>Presentation of papers at conferences/meetings (oral or poster)</u>
Name of all authors, year, title of paper/lecture, name of meeting, place

Shriki O., Dotan A. and Ben-Sasson Shay, 2018, Dynamical implications of optimal temporal information encoding in recurrent spiking networks, 2018, *AREADNE 2018 (Research in Encoding And Decoding of Neural Ensembles)*, Santorini, Greece.

Fekete T., Omer D., Kazunori O., Grinvald A., van Leeuwen C., and **Shriki O.**, Critical Dynamics, Anesthesia and Information Integration, 2017, *26th Annual Meeting of the Israeli Society for Neuroscience*, Eilat, Israel.

Levi-Aharony H., Alkoby O., Tishby N. and **Shriki O.**, 2016, A Quest for the Cortical Representation of Subjective Surprise With a Virtual Reality Neurofeedback Platform, *6th International BCI meeting*, Asilomar, CA, USA.

Arviv O., Goldstein A. and **Shriki O.**, 2015, Probing the E/I balance in large scale stimulus-evoked and resting-state activity of the human brain, *Neural Coding, Computation and Dynamics*, Bilbao, Spain.

Arviv O., Sheintuch L., Medvedovsky M., Goldstein A., Friedman A. and **Shriki O.**, 2014, Deviations from critical dynamics in inter-ictal epileptiform activity. *Annual meeting of the Society for Neuroscience***,** Washington DC, USA.

Shriki O., Alstott J., Carver F., Holroyd T., Henson R., Smith M. L., Coppola R., Bullmore E., and Plenz D., 2013, Neuronal Avalanches in the Resting MEG of the Human Brain. *Computational and systems neuroscience*. Salt-Lake City, UT.

Shriki O., Alstott J., Carver F., Holroyd T., Henson R., Smith M. L., Coppola R., Bullmore E., and Plenz D., 2011, Signatures of Criticality in Human Brain Dynamics. *Annual meeting of the Society for Neuroscience***,** Washington DC.

Shriki O., Alstott J., Carver F., Holroyd T., Henson R., Smith M. L., Coppola R., Bullmore E., Plenz D., 2011, Criticality in the resting brain: an MEG study, *Human Brain Mapping*, Quebec, Canada.

Shriki O., Kohn A. and Shamir M., 2011, Spike latency code for orientation discrimination and estimation by primary visual cortical cells, *Computational and systems neuroscience*, Salt-Lake City, UT.

Shriki O., Optimal Information Representation in Sensory Recurrent Networks that Operate near Bifurcation Points, *Computational and Systems Neuroscience 2004*, Cold-Spring Harbor, NY.

(c) Presentations at informal international seminars and workshops

(d) Seminar presentations at universities and institutions

Year, department, university/institution, title of presentation

2020, Gonda Center for Brain Sciences, BIU, Critical Brain Dynamics: Theoretical and Experimental Perspectives.

2019, AFRL, US Air-Force Research Labs, Wright-Patterson AFB, Dayton Ohio, Monitoring the Pilot's Brain for Better Flight Safety.

2018, ATR, Advanced Telecommunications Research Institute, Kyoto, Japan, Critical brain dynamics: Theory and Experiment.

2018, Dept. of Physics, WIS, Critical Brain Dynamics: Theory and Experiment.

2017, Dept. of Psychology, TAU, Why Sensory Deprivation and High Plasticity may lead to Hallucinations and Synaesthesia: A Computational Perspective.

2017, Dept. of Neurobiology, WIS, Why Sensory Deprivation and High Plasticity may lead to Hallucinations and Synaesthesia: A Computational Perspective.

2016, Dept. of Psychology, HUJI, Why Sensory Deprivation and High Plasticity may lead to Hallucinations and Synaesthesia: A Computational Perspective.

2016, Neurobiology Dept., Technion, Critical dynamics in resting and evoked human brain activity.

2015, Dept. of Psychology, HUJI, How Sensory Deprivation and High Plasticity may lead to Hallucinations and Synaesthesia: An information theoretic perspective.

2014, Bernstein Center for Computational Neuroscience, Goettingen, Germany, Monitoring the balance of excitation and inhibition in the human brain using neuronal avalanches

2014, Donders Center for Brain, Cognition and Behavior, Nijmegen, The Netherlands, Monitoring the balance of excitation and inhibition in the human brain using neuronal avalanches

2013, Columbia U./ Princeton U. (USA), Neuronal Avalanches and Criticality in the Human Brain.

2012, BIU/ WIS/ TAU/ HUJI, Neuronal Avalanches in the Resting MEG of the Human Brain.

2011, Neurobiology Interest Group, NIH (Bethesda, MD, USA), Neuronal Avalanches in the Resting MEG of the Human Brain.

2010, Neurobiology Dept., Technion, Spike Latency Coding of Orientation in the Primary Visual Cortex.

Patents

2013, **Shriki O.**, Plenz D., Meisel C., Tononi G., Monitoring the effects of sleep deprivation using neuronal avalanches, US patent 20160198968 A1.

2013, **Shriki O.**, Yosef Koralkin, Guy Slaton-Morgenstern, Nir Geva, Multilevel Hazard Detection System, US patent 9424731 B2.

2015, **Shriki O.**, Yosef Koralkin, Nir Geva, Method and system for detecting residential pests, US patent 9606226 B2.

Research Grants

2018-2020, JOY, Shriki O. [PI], "Neuromarkers for emotional resilience and vulnerability to sleep deprivation", annual amount $40,000, total amount $80000.

2018-2019, MAFAT, Shriki O. [PI], "Development of EEG-based measures for detecting G-induced loss of consciousness in pilots", total amount $42,700.

2018, ABC robotics initiative (Ben-Gurion University of the Negev), Shriki O. [PI] and Artemiadis P.[PI], "Hybrid Brain-Machine Interfaces for Controlling Robotic Swarms", annual amount, $15,000 for each PI.

2017-2021, Israel Science Foundation, Individual Investigator Grant (504/17), Shriki O.[PI], "Longitudinal Monitoring of Measures of Brain Connectivity and Dynamics in Neurological and Neuropsychiatric Disorders - Experiments and Computational Modeling", annual amount $70,380, total amount $281,500.

2017-2019 KAMIN (Innovation Authority), Shriki O. [PI], "Mobile EEG system for monitoring brain activity of patients with epilepsy and for seizure prediction", average annual amount $121400, total amount $242,800

2017-2019, MAFAT, Shriki O. [PI], "EEG and eye movement evaluation during exposure to vestibular illusion", average annual amount $13300, total amount $38000.

2017-2019, MAFAT, Shriki O. [PI], "Long term effects of hypoxia on cognitive function using EEG and ECG monitoring during the exposure", average annual amount $13300, total amount $26600.

2016, Israel Science Foundation, Grantees: Shriki O.[PI], Ofer Yizhar [PI], Grant for a 3-day international workshop titled "Finding the right balance: on the interplay between excitation and inhibition in neural dynamics", total amount $31700.

2015-2018, Shriki O.[PI], Air Force Office of Scientific Research (AFOSR), US Air Force, "NeuroFalcon – Neurotechnology for Fast Assessment of Loss-of-CONsciousness ", average annual amount $112,445, total amount $337,336.

2014-2017, Israel Science Foundation, Individual Investigator Grant (754/14), Shriki O.[PI], "Altered Excitation-Inhibition Balance in Neuropsychiatric and Neurological Disorders - Novel Analysis Tools and Computational Modeling", annual amount $57,400, total amount $172,200.

2014, Israel Science Foundation, New Researcher Equipment Grant, Shriki O.[PI], "Advanced Scientific Equipment and Instrumentation for the Computational Psychiatry Lab", total amount $50,000.

2014-2017, Infrastructure in Information Technology and Brain Sciences (Tashtiot), Israel Ministry of Science, Grantees: Hendler T.[PI], Shriki O.[C], Friedman D.[C], Dar R.[C], Bronstein A.[C]. "Can the brain cure itself? Combined imaging approach for closed-loop brain-modulation/regulation", total amount $390,000, annual amount for my lab $23,500, total amount for my lab $70,500.

Present Academic Activities

<u>Research in progress</u>

Self-regulation of critical brain dynamics by means of EEG neurofeedback, Dr. Nir Getter (Postdoctoral fellow), Dr. (MD) Miriam Guendelman, expected date of completion: Aug. 2020.

Schizophrenia as a Computational Pathology: Experiments and Theory, Erez Wolfson (PhD student), Prof. Yonatan Loewenstein (HUJI, co-supervisor), expected date of completion: Mar. 2020.

Longitudinal Monitoring of Measures of Brain Connectivity and Dynamics in Patients with Schizophrenia, Miriam Dissen Ben Or (PhD student), expected date of completion: Sep. 2023.

Information Maximization in Spiking Neuronal Networks, Shay Ben-Sasson (PhD student), expected date of completion: Sep. 2020.

How sensory deprivation leads to hallucinations - a computational perspective, Aviv Dotan (PhD student), expected date of completion: Feb. 2021.

EEG-based Metrics for Assessing Cognitive Workload, Lahav Foox (PhD student), expected date of completion: Sep. 2022.

Monitoring EEG during Spatial Disorientation, Gil Geva (PhD student), expected date of completion: Sep. 2022.

Brain-computer interfaces based on neuronal avalanches and spatio-temporal patterns of activity. Daniel Polyakov (PhD), expected date of completion: Sep. 2023.

Monitoring spatial attention during cognitive tasks using the SSVEP BCI paradigm, Asaf Harel (PhD student), expected date of completion: Sep. 2022.

Understanding EEG dynamics in the epileptic brain for better clinical assessment: a machine learning approach, Miriam Guendelman (PhD student), expected date of completion: Sep. 2022.

<u>Books and articles to be published</u>

In preparation:

1. Dotan A.[S] and **Shriki O.**[PI], Tinnitus-like “hallucinations” elicited by sensory deprivation in an entropy maximization based model for plasticity in early auditory processing.
2. Ben-Sasson S. [S], **Shriki O.** [†PI], Fekete T. [†PD], Towards viable EEG-based seizure prediction: impact of preprocessing, feature type and machine optimization. († - equal contribution)
3. Lombardi F.[PD], de Arcangelis L. [PI], Herrmann H. J. [C], Plenz D. [C] and **Shriki O.** [PI], Dynamics of quiet times between neuronal avalanches and alpha band oscillations.
4. Aharon S. [S] and **Shriki O.**[PI], EEG-based Cognitive Workload Estimation using Deep Convolutional Neural Networks.
5. Wolfson E. [S], Loewenstein Y. [PI] and **Shriki O.** [PI], Multi Scale Entropy assessment of resting-state MEG as a biomarker for schizophrenia.

Submitted for publication (indicate journal):

1. Fekete T. [PD], Hinrichs H. [C], Sitt J. D. [C], Heinze H. J.[C], **Shriki O.** [PI], Multiscale criticality measures as general-purpose gauges of proper brain function (PNAS).
2. Sarracino A.[S], Arviv O.[PD], **Shriki O.**[C] and de Arcangelis L.[PI], Predicting brain evoked response to external stimuli from time correlations of spontaneous activity (Physical Review Letters).

3. Lombardi F.[PD], **Shriki O.** [C], Herrmann H. J. [C] and de Arcangelis L. [PI], Long-range Temporal Correlations in the Broadband Resting state Activity of the Human Brain revealed by Neuronal Avalanches (Neurocomputing).

Additional Information

Add any other information, which is of relevance to your academic/professional background and experience.

Conferences organization

1. 2019, Israel Brain Technologies, 2-day meeting, Tel-Aviv, Member of the steering committee.
2. 2016, Finding the right balance: on the interplay between excitation and inhibition in neural dynamics, 3-day international workshop, Mitzpe Ramon.
3. 2016, Interdisciplinary Psychiatry: From basic science to clinical applications, 1-day, Hebrew University, Jerusalem.
4. 2015, Brain-Computer Interface Workshop, 1-day, Ben-Gurion University, Beer-Sheva.

BrainTech Community at BGU

Established in October 2018 a community of undergraduate and graduate students, which centers on brain technologies. The community meets on a monthly basis for relevant lectures and hands-on experience. Initiated and Co-organized the 'Brain Gurion' BrainTech Hackathon (March 6-7, 2019). The community has been recently extended to a national community with branches at multiple universities in Israel and many events: https://www.brainstormil.com/.

Synopsis of research, including reference to publications and grants in above lists

Research in the lab involves experimental work, data analysis and computational modeling aimed at developing new insights into psychiatric and neurological phenomena. In addition, the lab explores various neurofeedback and brain-computer interface paradigms. Described below are the major lines of research in the lab.

Neuronal Avalanches in Resting and Evoked Brain Activity

Neuronal avalanches are spatio-temporal clusters of activity, which exhibit a power law distribution of their sizes. The power law distribution is an indication that the brain operates at or near a critical state, which reflects an exquisite balance of excitation and inhibition. In recent years, numerous studies have found that the brain at resting-state displays many features of a critical state and in particular neuronal avalanches. We examined whether stimulus-evoked activity can also be regarded as critical and investigated the relation between resting-state activity and stimulus-evoked activity from the perspective of criticality. This work was published in the *Journal of Neuroscience* (ref. 10 in refereed papers, Arviv et al.). In a more recent project, we focused on the realtionship between neuronal avalanches and time-frequency analysis in both resting state and evoked activity. This work was recently published in *Scientific Reports* (ref. 20 in refereed papers, Arviv et al.). In ref. 15 in refereed papers we show that power law size distribution of neuronal avalanches is not enough for infering that a system is critical, and propose a set of additional mesaurs to assess genuine criticality.

Biomarkers for Brain Disorders

Several neurological disorders, such as epilepsy, and neuropsychiatric disorders, such as schizophrenia, are associated with an altered excitation-inhibition balance (EIB) in the underlying neuronal networks as well as with altered connectivity. A major line of research in the lab focuses on constructing sensitive biomarkers for these and other brain disorders based on non-invasive recordings of brain activity, in particular using EEG (Electroencephalography) and MEG (Magnetoencephalography). We apply methods based on the theory of critical brain dynamics, as well as analyses of network connectivity and signal complexity. Multiple studies in cortical cultures have shown in the past that measurs of critical brain dynamics are sensitive to altered EIB, but translating this to human data requires further work. In addition to data collection and analysis, we explore neuronal network models to gain better insights into the relationship between altered EIB and network dynamics as well as into the plasticity that may shape the EIB, restore it and maintain it. Representative papers are refs. 13 and 16 in refereed papers. In Ref. 16 (Fekete et al.), we extended the basic neuronal avalanche metrics to what we term 'multi-scale criticality' measures and applied them to voltage-sensitive dye data from different animals under different types of anesthesia. This work suggested that anesthesia pushes the system to either sub- or super critical dynamics. The paper also describes a computational model that provides more insights into the findings. Ref. 1 under submitted papers demonstrates the utility of multi-scale criticality measures in the context of human data from disorders of consciousness, schizophrenia, mild cognitive impairment and epilpesy. We have shown that these metrics are very sensitive to differences between patients and healthy controls and to differences among sub-populations in the context of disorders of consiousness.

Ref. 6 under papers in peparation demonstrates our work using measures of signal complexity, in this case, multi-scale entropy (MSE). We found substantial differences between schizophrenia patients and control subjects. In another project, we constructed graphs of the underlying connectivity using several methods and applied to them several graph-theoretical metrics. The results show substantial differences between schizophrenia patients and controls in several frequency bands.

Longitudinal Monitoring of Measures of Brain Connectivity and Dynamics in Neurological and Neuropsychiatric Disorders

Dynamic changes in the clinical and behavioral symptoms of neurological and neuropsychiatric disorders are expected to manifest in changes in the underlying neural dynamics. However, most studies that look for neural correlates of disease symptoms focus on comparing patients and control subjects using single-time measurements. Moreover, although several quantitative measures of brain activity display significant differences between patients and control subjects, there is a substantial overlap between the populations, limiting the interpretation and utility of these measures. Analyzing longitudinal changes in measures of brain activity and correlating them with day-to-day behavioral and clinical changes is expected to be much more informative. We have clinical longitudinal EEG data of epileptic patients and we are now starting to collect longiudinal EEG data from epileptic patients at their home environment over extended periods. We are also collectinng longitudinal EEG data from patients with schizophrenia at two mental health centers and are expected to obtain very soon a large database with longitudinal EEG data from patients with schizophrenia. This research is supported by ISF grant 504/17.

Network Dynamics in the Epileptic Brain

To investigate network dynamics in the epileptic brain, we first applied the neuronal avalanche analysis to resting-state MEG data from epileptic patients (not during a seizure). We found substantial deviations from critical dynamics in the inter-ictal activity of these patients. The patients show higher values of the gain parameter (σ) and of the avalanche exponent (α) compared to healthy controls, reflecting an excitation dominated-state in the patients. We also separated the data into periods with and without inter-ictal epileptiform activity and found that the avalanche metrics differ substantially between these two types of periods. A paper about these findings was published in the *Journal of Neuroscience* (ref. 13 in refereed papers). More recently, we have analyzed a large EEG database of the EU, which contains a few days of EEG from each patient together with labeling of the seizures. We extraced a wide range of mesaures from the data and applied machine learning algorithms to classify between interictal periods (at least 4 hours from a seizure) and preictal (1 hour before a seizure). Our algorithms reached a high performance in terms of the Area Under the Curve (AUC) of the Receiver Operating Charatreristic (ROC) – 97%. Furthemore, using a wide range of 'reverese-engineering' methods, we were able to identify which EEG features are more infromative and in which direction they typically change prior to a seizure. Thus, the machine learning work provide basic insights into the underlying changes in network dynamics that take place just before a seizure. We prepared draft of a paper about this project (Ref. 3 under papers in preparation). We also analyzed the pre-ictal EEG data using a wide range of dimensionality reduction methods and examined the trajectories in the low-dimensional phase-space (PhD project of Dr. Miriam Guendelman). The findings provide further insight into the dynamical changes prior to a seizure.

Neurofeedback on Metrics of Critical Brain Dynamics

The goal of this research is to develop novel neurofeedback (NF) approaches for Epilepsy and other disorders. We developed an in-house NF software which performs online neuronal avalanche analysis on the incoming EEG and reflects to the subject an ongoing estimate of the underlying neural gain. We recently completed a first batch of experiments where subjects performed 5 days of authentic NF training and 5 days of sham NF (with the order counter-balanced across subjects). Our preliminary results show that subjects can indeed modulate this parameter, and that it affects their performance in several cognitive tasks. If successful, this NF paradigm could be used by epileptic patients as a counter measure when there is a seizure alert.

Computational Modelling Related to Excitation-Inhibition Balance and Critical Dynamics

We developed neuronal network models that optimize information represetnation and showed that they approach a critical point in their dynamics, which can be thought of as the transition from normal amplification of inputs to hallucinations. Moreover, these networks can 'experience hallucinations' or develop 'synaesthesia' under conditions of sensory deprivation, consistent with well-known experimental findings. Part of this work is summarized in ref. 11 and 12 under refereed papers and in ref. 1 under papers in preparation. The long-term goal of this line of research is to construct simulations of cortical networks with inherent plasticity that can provide insights into neurological and neuropsychiatric disorders. We have extended the information maximization network models from simplified rate-model neurons to spiking neurons (integrate-and-fire), which can display a much richer dynamical repertoire. The main questions are whether the evolved networks exhibit irregular firing, similar to cortical networks, but also such phenomena as neuronal avalanches. Indeed, we recently obtained preliminary evidence for the emergence neuronal avalanches in these networks. We now examine the evolution of these networks when trained using natural auditory stimuli (PhD project of Shay Ben-Sasson).

Brain-Computer Interfaces

Brain Computer Interfaces (BCI) allow for direct communication between brain activity and external devices. They can be used for purposes such as robot control and communication tools for disabled people, such as ALS patients. We developed a method for evaluating the signal-to-noise ratio of subjects in the P300 BCI paradigm, which could be used to adapt the BCI to each subject (Ref. 17 under refereed papers, Artzi and Shriki). In another project, we have studied the interaction between human learning and machine learning over long time scales of a few days in the context of a motor-imagery BCI (Ref. 21 under refereed papers, Abu-Rmileh et al.). We also investigated the utility of echo-state networks for classifying motor-imagery data (Ref. 4 under submitted papers). At present, there are two ongoing projects on BCI in the lab. One focuses on a novel BCI paradigm based on spatio-temporal patterns of brain activity for decoding mental-speech imagery. The other project uses the SSVEP (Steady-State Visually Evoked Potential) paradigm to develop a novel approach for monitoring subject spatial attention during cognitive tasks.

Monitoring the Pilot Brain

Operational flight runs the risk of facing substantial physiological and cognitive obstacles, such as spatial disorientation, drowsiness, high cognitive load and even loss of consciousness during high-G maneuvers. Detecting such events in advance and alerting the pilot is critical for flight safety. However, even though most aircraft systems are monitored, to date no tools for monitoring the cognitive state of the pilot, which could help curtail human errors and improve flight safety, exist. We develop a solution based on integrating multiple sources of information with an emphasis on brain activity as measured through EEG. The system is designed to be embedded in combat pilot helmets, continuously monitor the pilot brain and generate flight safety alerts for the pilot. The system focuses on drowsiness, cognitive workload, G-induced loss-of-consciousness (G-LOC), hypoxia and spatial disorientation. Experiments on all five aspects are carried out together with the aeromedical unit of the Israeli Air-Force (IAF). In all five cases, we utilize advanced EEG data analysis methods to analyze concurrent recorded brain activity and identify the most informative measures for generating relevant alerts on short time scales. The information from these measures is then integrated using machine learning, at each point in time, to produce an optimal decision. Below is a brief description of our research on each of these components.

G-LOC: G-LOC is defined as "a state of altered perception wherein (one's) awareness of reality is absent as a result of sudden, critical reduction of cerebral blood circulation caused by increased G force". A G-LOC episode typically comprises a phase of absolute incapacitation followed by a phase of relative incapacitation, during which the person suffers from confusion and disorientation. We joined 5 Israeli Air-Force pilot cadet delegations for their centrifuge training (4 times to the Netherlands, once to Germany) and collected data from over 40 subjects using a gel-based non-wireless EEG system. We analyzed the data using a wide range of EEG measures and developed a unique algorithm that can identify deviations in the EEG and indicate within seconds an upcoming loss of consciousness. The collected data contain a few G-LOC cases that help validate the algorithm, but more data must be acquired to improve reliability and enable pursuing additional tests. Importantly, these experiments have shown the resilience of EEG electrodes under high-G (9G) maneuvers. The project is funded by a grant from MAFAT.

Hypoxia: Hypoxia refers to reduced concentration of oxygen in body tissues, which can occur at high altitudes. Its effects include fatigue, confusion, euphoria, inability to concentrate, impaired decision-making, impaired psychomotor performance and even loss of consciousness. Several lines of evidence indicate that EEG measures can be sensitive to hypoxia. We began experimentation employing the ROBD system (Reduced Oxygen

Breathing Device), which simulates hypoxia, at the Aeromedical unit. Our EEG system is worn beneath the pilot helmet. We plan to conduct future experiments within the pressure chamber, which affects not only the oxygen level but also the surrounding pressure. The project received funding from MAFAT.

Spatial disorientation: Spatial disorientation during flight occurs when an aircrew member either erroneously perceives or altogether fails to perceive the location, movement, or altitude of her aircraft. Statistical analysis found that 5% - 10% out of all aviation accidents are caused by spatial disorientation, out of which 90% are lethal. We used a rotating chair to induce the somatogyral illusion, and monitored brain activity using EEG and eye movements using special eye-tracking glasses. We have already collected data from more than 15 subjects and are actively pursuing the experiments. Our analyses identified an EEG measure that indicates when subjects experience spatial disorientation, even though they are not aware of it (unrecognized spatial disorientation). The aeromedical unit has purchased a unique training device for spatial disorientation, called Vertigon. It can generate a wide range of spatial disorientation conditions and once operational, will be used to perform further experiments as well. The project was funded by a grant from MAFAT.

Cognitive workload: Operational flight requires integrating various mental resources, such as working memory, attention and decision making. However, our brains are limited in their resources for processing and integrating information at their disposal. The concept of cognitive load generally refers to the relative load on these limited resources. We develop EEG measures that reflect the cognitive workload of subjects. To this end, we first pursued a preliminary study utilizing a simple video game comprising several levels of difficulty and obtained promising EEG-based load prediction results (MA thesis of Lahav Foox). We are now performing another set of experiments where we use multiple versions of the n-back task to construct an individual EEG-based workload scale for each subject. We test the utility of this scale to predict performance in other cognitively demanding task, in particular under more ecological conditions, such as flight simulator training. We are planning a project, which involves recording EEG from pilot cadets during flight simulator training as part of their flight screening curriculum. We expect to observe a decrease in workload along the training process, which would inversely correlate with individual cadet skill acquisition. EEG evaluation of the load could be used for screening cadets and for custom tailoring the training process to best suit each individual. In operational flight, it could be used to adapt the display in real time and for post-flight debriefing.

Drowsiness: Sleep deprivation has detrimental effects on cognitive functioning and can lead to slow reactions and poor decision making. We performed several experiments during Israeli Air-Force prolonged wakefulness training. Aircrew and UAV (Unmanned Aerial Vehicles) operators were kept awake for 32-36 hours and we collected data every 4-6 hours. We acquired high quality EEG data (64 electrodes) from more than 40 subjects during both resting-state (4 min) and a psycho-motor vigilance (PVT) task (3 min). We found that the branching parameter from the avalanche analysis is correlated with the reaction time and can be used to predict it. We are now carrying further experiments and develop machine learning approaches to improve the sensitivity and selectivity of our prediction.

Teaching Statement

Teaching, in tandem with research, has long been an integral part of my professional development and I very much enjoy teaching. During my PhD studies, in addition to being a TA of course on neural networks, I also developed and taught my own course, an introductory math course for students with non-mathematical background who were beginning the PhD program in computational neuroscience. During this period, I developed my approach to teaching, which emphasizes, in addition to the formal subject matter, the role of intuition and visualization in mathematical and computational topics and is based on extensive interaction with the students.

Following my PhD, I decided for ideological reasons to combine research with teaching at a residential high school for gifted students in Jerusalem. For nine years, I taught physics there as well as courses in the philosophy of science, ethics in science and of course, neural computation. Since I believe that the most effective learning is one in which the learner is active, I also initiated and supervised many research projects. I even established a research laboratory at the school, where students could carry out research projects in brain sciences and in robotics. During these years, I also obtained a teaching certificate from the Department of Science Teaching at the Weizmann Institute of Science. The courses in that two-year program were illuminating and provided me with many important insights and effective teaching tools, which I still use today.

My major goal as a teacher is to provide my students with skills, in particular for problem solving and critical thinking. It is important for me to challenge them and expose them to novel perspectives and ways of thinking. Good problem-solving skills require using metacognitive processes, namely personal reflection on the thought process (e.g., "Why am I solving the problem this way? Could there be other ways?"), and it is important to emphasize and demonstrate that. Besides teaching thinking skills, rather than just knowledge of the topic, it is important for me to share my enthusiasm and ideally make the students love the subject matter as much as I do.

My teaching strategy in courses that are based on frontal teaching is to engage the students continuously by encouraging them to participate and ask questions. This allows me to identify misunderstandings and repeat certain subjects when required. I also use humor when possible and sometimes relevant educational video clips to illustrate points and make the lessons more engaging. In the "Computation and Cognition" courses I often run simulations of the relevant model on my computer and encourage the students to predict what will happen given the choice of parameters. To promote problem solving skills, I sometimes let them quietly work on a problem that I present during the lesson. The home exercises also include open problems that demand analytical thinking. The full electronic lecture notes and presentations are available to the students on the online platform (Moodle). I also record my lessons using the university equipment, so that student can watch the presentation or lecture notes while hearing me. The feedback on that from the students is very good and they often tell me that they may listen to a particular lecture several times.

To assess the engagement and comprehension of my students during the semester, I use the Kahoot framework. Every lecture starts with a 5-min quiz on the material from the previous lecture, which includes 3-5 multiple choice questions. I often include a funny trivia question on the brain, which is not directly related to the course. The students see the questions on the projector and answer as correctly and as quickly as they can using the Kahoot smartphone app. The winners get small funny prizes, typically giveaways from scientific conferences. In my frontal courses I use a final open exam, which covers the material. My exams are not easy, but are not meant to be to very hard. The major goal is to force the students, as they prepare to the exam, to integrate the material and reflect upon it.

As mentioned above, I believe that student-centered learning, where the student actively learns in an hands-on manner is the most effective learning process. To this end, I established a course on MATLAB and neural data analysis which focuses on hands-on activity. The lessons take place in a computer class, where the students work in pairs. Following a brief presentation of the relevant background for each exercise, the students work on their own, and most the time we (the TA and myself) walk among them and provide one-on-one assistance. The assessment in this course is based on 5-6 mini-projects and a final project which integrates the material (currently, it involves analysis of data from an EEG brain-computer interface experiment and building an algorithm for trial-by-trial classification).

In the future, I plan to learn and incorporate more tools for engaging and effective teaching. It is also important for me to keep the courses relevant and updated. For example, in the advanced computation and cognition course I teach the subject of Deep Learning, and it is important for me to expose the students to new models from the front of the research in this field.