Erik P Hoel, PhD
Curriculum Vitae
Research assistant professor

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University education

PhD, 2010 – 2016	University of Wisconsin-Madison, WI Advisor: Giulio Tononi, M.D., PhD. Thesis: "Brain organization and information integration"
B.A. 2006 – 2010	Hampshire College, MA Advisor: Jane Couperus, PhD. Theses: "A Graph-Theoretic Approach to the Neural Correlates of Consciousness" and "Closing the Explanatory Gap in Philosophy of Mind"

Research interests

I combine information theory, causal analysis, and modeling to understand how the higher scales of complex systems emerge from their lower scales. A further goal of my research is to understand in a formal quantitative manner how causal structure changes in systems such as graphs or deep neural networks. The potential outcome of my research is to improve causal model choice, guide scientific experiments, and highlight the importance of model choice in considering causation, information, and function in physical, artificial, and biological systems. Additionally, I am interested in how formal measures based on brain dynamics can be used to capture both the level and content of consciousness.

Publications

a. Journal articles

1. Mattsson, S. & **Hoel, E.** (In prep) Identifying the informative macroscales of deep neural networks.
2. **Hoel, E.**, Klein, B., Swain, A., Griebenow, R., & Levin, M. (In prep) Evolution leads to the emergence of higher scales: An analysis of macro-nodes in protein interactomes across the tree of life.
3. Kleiner, J. & **Hoel, E.** (2020). Falsification and consciousness. *arXiv preprint arXiv:2004.03541*.
4. Biswas, S., Manicka, S., **Hoel, E.**, & Levin, M. (In press) Gene Regulatory Networks Exhibit Several Kinds of Memory: Quantification of Learning in Biological and Random Transcriptional Networks.

5. **Hoel, E.** & Levin, M. (In press at *Cell Systems*). Emergence of higher levels in biological systems: Analysis of causal structure and control in development and beyond.
6. Griebenow, R., Klein, B., & **Hoel, E.** (In press at *Journal of Physics: Complexity*). Finding the right scale of a network: Efficient identification of causal emergence through spectral clustering. *arXiv preprint arXiv:1908.07565*.
7. Klein, B., & **Hoel, E.** (2020). The Emergence of Informative Higher Scales in Complex Networks. *Complexity, 2020*.
8. Wenzel, M., Han, S., Smith, E. H., **Hoel, E.**, Greger, B., House, P. A., & Yuste, R. (2019). Reduced Repertoire of Cortical Microstates and Neuronal Ensembles in Medically Induced Loss of Consciousness. *Cell systems*, *8*(5), 467-474.
9. Albantakis, L., Marshall, W., **Hoel, E.**, & Tononi, G. (2019). What Caused What? A quantitative Account of Actual Causation Using Dynamical Causal Networks. *Entropy*, *21*(5), 459.
10. **Hoel, E**. (2017) When the map is better than the territory. *Entropy*, *19*(5), 188. Selected for the issue cover.
11. **Hoel E.,** Albantakis, L., Marshall, W., & Tononi, G. (2016) Can the macro beat the micro? Integrated information across spatiotemporal scales. *Neuroscience of Consciousness*, no.1.
12. **Hoel, E**., Albantakis, L., Cirelli, C., & Tononi, G. (2016) Synaptic refinement during development and its effect on slow-wave activity: a computational study. *Journal of neurophysiology* 115.4: 2199-2213.
13. **Hoel, E.,** Albantakis, L., & Tononi, G. (2013) Quantifying causal emergence shows that macro can beat micro. *Proceedings of the National Academy of Sciences* 110.49: 19790-19795 (2013).

b. Books

1. **Hoel, E.** (2021). *The Revelations*. Abrams Books, Inc, NYC, New York, USA.
2. **Hoel, E.** (2022). *The World Behind the World: Consciousness as the last frontier of science*. Simon & Schuster, Inc, NYC, New York, USA.

c. Peer-reviewed conference publications

1. Aubert-Kato, N., Witkowski, O., **Hoel**, **E.,** Bredeche, N. (2016) Towards Detecting the Emergence of Agency in Evolved Artificial Chemistries. Carlos Gershenson, Tom Froese, Jesus M. Siqueiros, Wendy Aguilar, Eduardo J. Izquierdo and Hiroki Sayama (eds.), *Artificial Life XV: Late- Breaking Proceedings of the Fifteenth International Conference on the Synthesis and Simulation of Living Systems*, 20–21.

Invited talks

1. "Causation as Information" at the Physics of Living Systems Lab, MIT, Boston, MA, USA. (2019)
2. "Quantifying emergence and reduction in complex systems" at *Complexity: From Cells to Consciousness*, Thessaloniki, Greece. (2018)
3. "A Way Forward for Consciousness Research" at *Causation and Complexity in the Conscious Brain,* Aegina, Greece. (2018)
4. "Causal Structure Across Scales" at Araya, Inc, Tokyo, Japan. (2018)
5. "Information and Causation" at the Info-metrics and Causal Inference workshop at Carnegie Mellon University, Pittsburgh, PA, USA.

6. "Quantifying Emergence and Reduction" at the Network Science Institute at Northeastern University, Boston, MA. (2018)
7. "Biological Organization Across Scales" at Tufts University, Medford, MA, USA.
8. "Emergence and Reduction" at Arizona State University, AZ, MA, USA. (2017)
9. "Macro vs Micro" at Hampshire College, Amherst, MA, USA. (2017)
10. "Free Will and Causation" at the London School of Economics, London, UK. (2017)
11. "Emergence, Free Will, and Causal Responsibility" at Yhouse, Inc, New York, NY, USA. (2017)
12. "Literature and the Hard Problem of Consciousness" at the Institute for Advanced Study, Princeton, NJ, USA. (2016)
13. "Brain Organization and Integrated Information" at the Neuroscience Training Program, University of Wisconsin-Madison, Madison, WI, USA. (2016)
14. "Causal Emergence and Neural Ensembles" at the NeuroTechnology Center at Columbia University, New York, NY, USA. (2015)
15. "Measuring Causal Emergence" at the Center for Theoretical Neuroscience at New York, NY, USA. (2015)
16. "How the Macro Beats the Micro" at the workshop on The Integrated Information Theory of Consciousness: Foundational Issues. (2015)
17. "Brain organization and the spatiotemporal scale of brain activity" for the Neuroscience Training Program seminar series, University of Wisconsin-Madison, Madison, WI, USA. (2015)
18. "The Limits of Reductionism" at Hampshire College, Amherst, MA. (2013)
19. "Graph Theory and the Neural Correlates of Consciousness" at Hampshire College, Amherst, MA. (2010)
20. "Electrophysiological Evidence of Pattern Completion and Separation in the CA1 Region of the Macaque Hippocampus" at New York University, New York, NY, USA. (2008)

Poster presentations

1. Aubert-Kato, N., Witkowski, O., **Hoel**, **E.**, Bredeche, N. (2016) *Decision Making in Messy Chemistries: Case Study with an Invasion-based Reaction Diffusion Scenario*. Proceedings of the International Conference on Unconventional Computation and Natural Computation.
2. **Hoel**, **E.**, Albantakis, L., Tononi, G. (2015) *The spatial and temporal scale of conscious experience*, presented at the Association for the Scientific Study of Consciousness.
3. **Hoel**, **E.**, Albantakis, L., Tononi, G. (2014) *Synaptic refinement and brain organization*. Presented at the Neuroscience Research Symposium of the Neuroscience Training Program.
4. Albantakis, L., **Hoel**, **E.**, Oizumi, M., Koch, C., Tononi, G. (2014) *Intrinsic causation and consciousness*. Presented at The Association for the Scientific Study of Consciousness.
5. **Hoel**, **E.**, Albantakis, L., Tononi, G. (2012) *The 'neural code' from the intrinsic perspective: Quantifying causal power at different spatiotemporal scales*. Present at Frontiers in Computational Neuroscience Conference.
6. **Hoel**, **E.**, Hogan, M., Couperus, J. W. (2010) *The network properties of conscious experience: relative blindsight, 'small worlds,' and functional connectivity*. Presented at The Association for the Scientific Study of Consciousness.
7. Couperus, J. W., **Hoel**, **E.**, Alperin, B. (2009) *Perceptual load modifies processing of distractor stimuli both in the presence and absence of target stimuli*. Presented at the Annual Meeting of the Cognitive Neuroscience Society.

Research positions

2018 – ongoing	TUFTS UNIVERSITY, Medford, MA **Research assistant professor, Allen Discovery Center**
2016 – 2018	COLUMBIA UNIVERSITY, New York, NY Advisor: Rafael Yuste, Professor of Biological Sciences **Postdoctoral researcher**
2016 – 2018	YHouse Inc, Hoboken, NJ **Co-founder; Co-chair of coordinating committee**
2016 – 2017	INSTITUTE FOR ADVANCED STUDY, Princeton, NJ Advisor: Piet Hut, Head of The Program of Interdisciplinary Studies **Visiting scholar**
2010 – 2016	UNIVERSITY OF WISCONSIN-MADISON, Madison, WI. Advisor: Giulio Tononi **PhD student**
2008 – 2010	HAMPSHIRE COLLEGE, Amherst, MA Advisor: Jane Couperus, Dean of the School of Cognitive Science **EEG lab manager**
2008	NEW YORK UNIVERSITY, New York, NY Advisor: Wendy Suzuki, Professor of Neural Science **NSF research internship**

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a. Honors and prizes

Forbes 30 under 30 in Science (2018); Foundational Questions Institute prize winner; NYC Emerging Writers Fellow; First place winner of the Writer's Digest Annual short story competition; Neuroscience Training Program Merit Scholarship; Honorable mention in the Writers of the Future Award; Hampshire College Faculty Choice Scholarship.

b. Awarded grants (contributed to or co-PI)

Templeton World Charity Foundation – Grant ID: TWCF 0273 (~$250,000); DARPA – Breaking the Code: engineering neural controllers and behavior in the hydra (~$7,500,000); Templeton World Charity Foundation – Grant ID: TWCF 0067/AB41 (~$2,500,000); Culture, Brain, and Development Grant: brain structure in ADHD; School of Cognitive Science Grant; Culture, Brain, and Development Research Assistantship Grant; School of Natural Science Grant; SURP at the Center for Neural Science at NYU, NSF-REU; Culture, Brain, and Development grant: neuronal development; Coppinger Grant to study human evolution.

Teaching

2014 – 2015	PEOPLE Program, Madison, WI

	Taught neuroscience to low-income minority high school students over the summer
2009	Hampshire College, Amherst, MA *TA: "Minds, Brains, Machines."*
2009	Hampshire College, Amherst, MA *TA: "Gene Cloning."*
2008	Hampshire College, Amherst, MA *TA: "Brain Mechanisms."*

Outreach and engagement

a. Organizations

I co-founded YHouse, Inc, a registered nonprofit organization based in New York City devoted to scientific outreach, innovative and transdisciplinary research, intellectual partnership, and public discourse tackling questions on awareness, consciousness, and the future of intelligence. We host ongoing programs of public lecture series, events, weekly meetups, and conversations about scientific and philosophical approaches to consciousness, often in partnership with other organizations.

b. Talks for the public

1. "Literature and the Problem of Other Minds" at YHouse, Inc, New York, NY, USA (2018)
2. "How We Experience" at The Center for Fiction, New York, NY (2018)
3. "How We Grieve" at The Center for Fiction, New York, NY (2017)
4. The Story Collider, The Caveat Center, Brooklyn, NY, USA (2017)
5. "The Threat of Artificial Intelligence," The Caveat Center, Brooklyn, New York, NY, USA.
6. "Emergence, Free Will, and Causal Responsibility," at YHouse, Inc, New York, NY, USA (2017).
7. "The Mind-Body Problem: The More Theories the Better?" at YHouse Inc, New York, NY, USA (2016)
8. "The Origins of Awareness," at *Chasing Consciousness: from cells to societies, neuroscience to machine awareness*. Rubin Museum of Art, New York, NY, USA (2016).
9. "The Hard Problem of Consciousness or the Hard Problem of Matter?" at *Chasing Consciousness: from cells to societies, neuroscience to machine awareness*. Rubin Museum of Art, New York, NY, USA (2016).

c. Press profiles

1. "New Math Untangles the Mysterious Math of Causality" in *WIRED* (2017)
2. "A Theory of Consciousness Can Help Build a Theory of Causality" in *Nautilus* (2017)

d. Essays and articles

1. "Enter the Supersensorium: a neuroscientific case for art in the age of Netflix." *The Baffler*, issue 46.
2. "Superintelligence vs. You: on the fanciful nature of dark futures" featured by the Medium editorial staff.

3. "Who Invented Memes? On the Impossibility of Originality in the Digital Age" featured by the Medium editorial staff.
4. "Will the Bitcoin bubble pop? Or Will It Envelop Us All?" in *Arc Digital* (2018)
5. "A Fiction for the Future" at The Center for Fiction's website (2017)
6. "Intellectuals defend the value of being intellectuals" in *Scientific American* (2017).
7. "Agent Above, Atom Below." The Foundational Questions Institute's essay contest Wandering Toward a Goal: How can mindless mathematical laws give rise to aims and intention? (2017).
8. "Fiction in the Age of Screens." *The New Atlantis* (2016), selected for the Best American Essays series.
9. "Why Do We Sleep?" *Big Questions Online* (2016).
10. "How to Mathematically Measure Consciousness." *The Daily Beast* (2016).
11. "*City on Fire* by Garth Risk Hallberg proves how Culturally Dominant Television Has Become." *The Atlantic* (2015).
12. "Why Free-Range Kids Are Healthier." *The Daily Beast* (2014).
13. "Science as a Subject of Art." *SciArt in America* (2013).
14. "A Review of Incomplete Nature: How Mind Emerged from Matter." The Neuroethics Blog of Emory University (2012).
15. "Framing and Responsibility in Consciousness Studies." The Neuroethics Blog of Emory *University* (2012).

References

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