Ari S. Morcos

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Research interests

Machine Learning and Deep Learning

My main research focus is to design and execute rigorous experiments to understand the solutions found by deep neural networks and most critically, their bottlenecks, so that we can intelligently design machine learning systems. I am also interested in developing methods to measure and induce abstract representations in neural networks.

Education

Harvard University   *Cambridge, Massachusetts, USA*
Ph.D. in Neurobiology   *Jul. 2011 - April 2016*
- Advisor: Christopher Harvey.
- Thesis: Population dynamics in parietal cortex during evidence accumulation for decision-making.

University of California, San Diego   *La Jolla, California, USA*
B.S. in Physiology and Neuroscience   *Sept. 2008 - March 2011*

Work and Research Experience

DeepMind   *London, UK*
Research Scientist   *Sep. 2016 - PRESENT*
- Using neuroscience-inspired techniques to understand and improve deep neural networks.
- Investigated properties of learned network solutions which are predictive of generalization ability, both in individual networks and across groups of networks.
- Developed new behavioral and introspective methods to measure, understand, and improve abstraction abilities in deep neural networks.

Harvard University   *Cambridge, Massachusetts, USA*
Graduate research with Christopher Harvey   *Jul. 2011 - April 2016*
- Developed an evidence accumulation task for head-restrained mice in virtual reality and used calcium imaging of activity in large neuronal populations along with novel computational analyses to study the neuronal population activity dynamics underlying decision-making.
- Using machine learning approaches that had not been applied to neuroscience data sets previously, we identified multiple major features of the population activity, including a distributed code among heterogeneous individual neurons, history signals for past events lasting seconds, and structured trial-trial variability that was predictive of past and future activity patterns.
- Together our results provide data that contradict the long-standing models of evidence accumulation and that propose a novel model of computation based on large-scale neuronal population dynamics.

Salk Institute for Biological Studies   *La Jolla, California, USA*
Undergraduate research with Fred H. Gage   *Jan. 2009 - Dec. 2010*
- Investigated the role of REST in adult neurogenesis.

Publications

Eslami SMA*, Rezende DJ*, Besse F, Viola F, **Morcos AS**, Garnelo M, Ruderman A, Rusu AA, Danihelka I, Gregor K, Reichert DP, Beusing L, Weber T, Vinyals O, Rosenbaum D, Rabinowitz NC, King H, Hillier C, Botvinick M, Wierstra D, Kavukcuoglu K, and Hassabis D. "Neural scene representation and rendering." *Science*, 15 Jun 2018; Vol. 360, Issue 6394, pp. 1204-1210. DOI: 10.1126/science.aar6170.
 Author contribution: A.S.M. designed and performed analysis experiments.

Morcos AS*, Raghu M, Sohl-Dickstein J, Bengio S. "Insights on representational similarity in neural networks with canonical correlation." *arXiv preprint. In submission to NIPS 2018.*

Ruderman A, Rabinowitz NC, **Morcos AS**, and Zoran D. "Pooling is neither necessary nor sufficient for appropriate deformation stability in CNNs." *arXiv preprint. In submission to NIPS 2018*.

Barrett DGT*, Hill F*, Santoro A*, **Morcos AS**, and Lillicrap T. "Measuring abstract reasoning in neural networks." *International Conference on Machine Learning (ICML)*, 2018. ***Selected for a long talk.***.

Morcos AS, Barrett DGT, Rabinowitz NC, and Botvinick M. "On the importance of single directions for generalization." *International Conference on Learning Representations (ICLR)*, 2018.

Morcos AS and Harvey CD. "History-dependent variability in population dynamics during evidence accumulation in cortex." *Nature Neuroscience*, 2016; 19(12):1672-1681. doi: 10.1038/nn.4403.

Kim HJ, Denli AM, Wright R, Baul TD, Clemenson GD, **Morcos AS**, Zhao C, Schafer ST, Gage FH, and Kagalwala MN. "REST Regulates Non-Cell-Autonomous Neuronal Differentiation and Maturation of Neural Progenitor Cells via Secretogranin II." *Journal of Neuroscience*, 2015 Nov 4;35(44):14872-84. doi: 10.1523/JNEUROSCI.4286-14.2015.

Morcos AS. "Mechanisms and applications of adult neurogenesis." *Saltman Quarterly*, 2009 (6):35-36. .

*indicates equal contribution

Workshop publications, theses, and abstracts

Morcos AS, Barrett DGT, Rabinowitz NC, and Botvinick M. "On the importance of single directions for generalization." *NIPS Workshop on Deep Learning: Bridging Theory and Practice*, Barcelona, Spain. December, 2017.

Morcos AS. "Population dynamics in parietal cortex during evidence accumulation for decision-making." *PhD Thesis, Harvard University*, April, 2016. https://dash.harvard.edu/handle/1/33493459.

Morcos AS and Harvey CD. "History-dependent variability in population dynamics during evidence accumulation in cortex." *Cosyne 2016*. ***Selected for an oral presentation.***, Salt Lake City, UT, USA. February, 2016.

Morcos AS, Kagalwala MN, Denli AM, McConnell MJ, Clemenson GD, Zhao C, and Gage FH. "The role of REST/NRSF in adult neurogenesis." *Society for Neuroscience*, San Diego, CA, USA. November, 2010.

Morcos AS. "Understanding the Protein-Protein Interplay of NRSF (REST) In Regulating Transcription." *UCSD Undergraduate Research Conference*, San Diego, CA, USA. 2009.

Awards, Honors, & Fellowships

2013-2016	**Stuart and Victoria Quan Pre-Doctoral Fellowship** Harvard Medical School	
2013	**Honorable Mention** NSF Graduate Research Fellowship	
2009-2010	**Research Scholar** Amylin Pharmaceuticals	
2009	**Summer Research Fellow** Howard Hughes Medical Institute	
2009	**Scholar** Alliance for Affordable Services	

Teaching Experience

2012	**Teaching assistant, MATLAB/Quantitative Methods Bootcamp** Harvard Medical School	