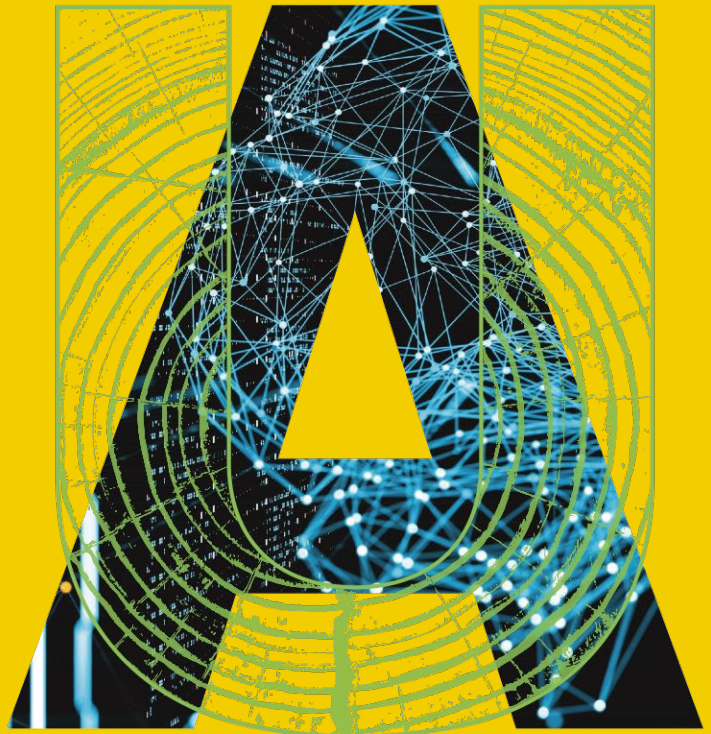
MACHINE LEARNING & THE BRAIN

Course Introduction

Alona Fyshe & Alex Murphy
Autumn Term 2023



UNIVERSITY OF ALBERTA

Course Outline

05 September 2023:	**Introduction to Neuroscience and Machine Learning**
12 September 2023:	**The Visual System & CNNs**
28 September 2023:	**Coding Workshop**
05 October 2023:	**Language Models & Language Neuroscience**
31 October 2023:	**Decision Making / Planning & Reinforcement Learning**

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Paper Presentations

Each student will present a paper in available classroom slots.

Papers are from the three sections of choice (vision, language & RL).

Aim for approximately 45-50 minute presentations, followed by a 30-35 minute class discussion.

Vision

Papers:

- Yamins et al. (2014)
- Horikawa & Kamitani (2017)
- Konkle & Alvarez (2022)
- Dobs et al. (2022)
- Bashivan et al. (2019)

Vision: Paper 1

Performance-optimized hierarchical models predict neural responses in higher visual cortex

Daniel L. K. Yamins[a,1], Ha Hong[a,b,1], Charles F. Cadieu[a], Ethan A. Solomon[a], Darren Seibert[a], and James J. DiCarlo[a,2]

[a]Department of Brain and Cognitive Sciences and McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139; and [b]Harvard-MIT Division of Health Sciences and Technology, Institute for Medical Engineering and Science, Massachusetts Institute of Technology, Cambridge, MA 02139

https://www.pnas.org/doi/10.1073/pnas.1403112111

Vision: Paper 2

Open access | Published: 22 May 2017

Generic decoding of seen and imagined objects using hierarchical visual features

Tomoyasu Horikawa & Yukiyasu Kamitani

Nature Communications **8**, Article number: 15037 (2017) | Cite this article

https://www.nature.com/articles/ncomms15037

Vision: Paper 3

Article | Open access | Published: 25 January 2022

A self-supervised domain-general learning framework for human ventral stream representation

Talia Konkle & George A. Alvarez

Nature Communications **13**, Article number: 491 (2022) | Cite this article

https://www.nature.com/articles/s41467-022-28091-4

Vision: Paper 4

RESEARCH ARTICLE | NEUROSCIENCE

Brain-like functional specialization emerges spontaneously in deep neural networks

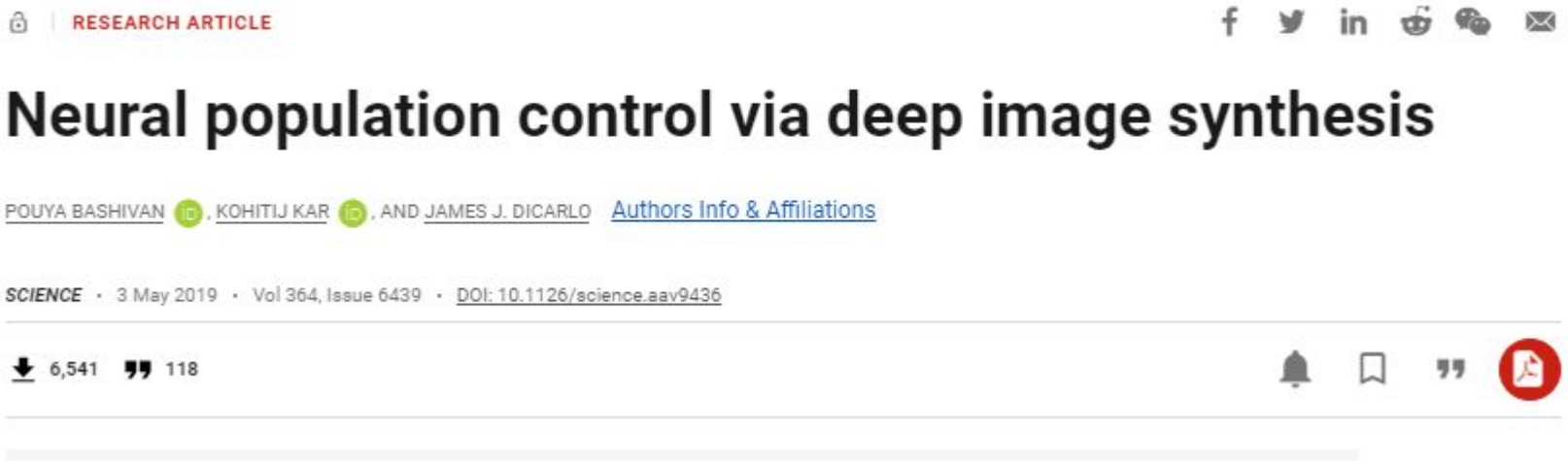
KATHARINA DOBS, JULIO MARTINEZ, ALEXANDER J. E. KELL, AND NANCY KANWISHER Authors Info & Affiliations

SCIENCE ADVANCES • 16 Mar 2022 • Vol 8, Issue 11 • DOI: 10.1126/sciadv.abl8913

12,545 15

https://www.science.org/doi/10.1126/sciadv.abl8913

Vision: Paper 5



https://www.science.org/doi/10.1126/science.aav9436

Language

Papers:

- Wehbe et al. (2014)
- Hollenstein et al. (2021)
- Jain & Huth (2018)
- Caucheteux & King (2022)
- Toneva & Wehbe (2019)
- Tuckute et al. (2023)

Language: Paper 1

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Simultaneously Uncovering the Patterns of Brain Regions Involved in Different Story Reading Subprocesses

Leila Wehbe, Brian Murphy, Partha Talukdar, Alona Fyshe, Aaditya Ramdas, Tom Mitchell

Published: November 26, 2014 • https://doi.org/10.1371/journal.pone.0112575

Article | Authors | Metrics | Comments | Media Coverage

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0112575

Language: Paper 2

ORIGINAL RESEARCH article

Front. Hum. Neurosci., 13 July 2021

Sec. Speech and Language

Volume 15 - 2021 | https://doi.org/10.3389/fnhum.2021.659410

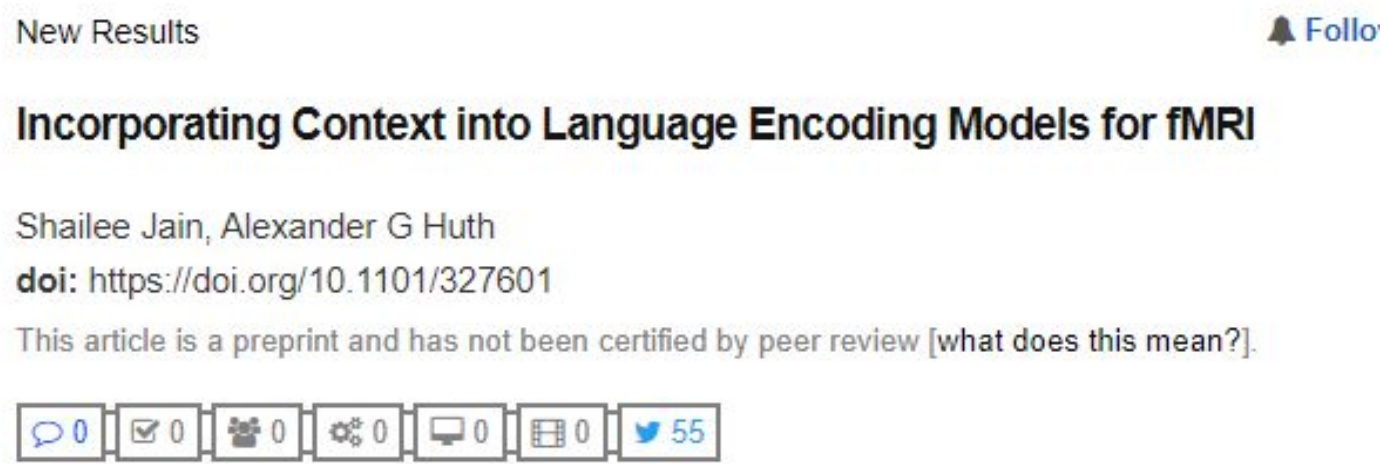
Decoding EEG Brain Activity for Multi-Modal Natural Language Processing

 Nora Hollenstein[1*] Cedric Renggli[2] Benjamin Glaus[2] Maria Barrett[3] Marius Troendle[4]  Nicolas Langer[4]

Ce Zhang[2]

https://www.frontiersin.org/articles/10.3389/fnhum.2021.659410/full

Language: Paper 3



New Results

Follo

Incorporating Context into Language Encoding Models for fMRI

Shailee Jain, Alexander G Huth

doi: https://doi.org/10.1101/327601

0 0 0 0 0 0 55

https://www.biorxiv.org/content/10.1101/327601v2

Language: Paper 4

Article | Open access | Published: 16 February 2022

Brains and algorithms partially converge in natural language processing

Charlotte Caucheteux & Jean-Rémi King

Communications Biology **5**, Article number: 134 (2022) | Cite this article

https://www.nature.com/articles/s42003-022-03036-1

Language: Paper 5

Interpreting and improving natural-language processing (in machines) with natural language-processing (in the brain)

Mariya Toneva
Neuroscience Institute
Department of Machine Learning
Carnegie Mellon University
mariya@cmu.edu

Leila Wehbe
Neuroscience Institute
Department of Machine Learning
Carnegie Mellon University
lwehbe@cmu.edu

https://proceedings.neurips.cc/paper/2019/file/749a8e6c231831ef7756db230b4359c8-Paper.pdf

Language: Paper 6

Driving and suppressing the human language network using large language models

Greta Tuckute[1,2], Aalok Sathe[1,2], Shashank Srikant[3,4], Maya Taliaferro[1,2], Mingye Wang[1,2], Martin Schrimpf[2,5,6], Kendrick Kay[7], Evelina Fedorenko[1,2,8]

1. Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139 USA
2. McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA 02139 USA
3. Computer Science & Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, MA 02139 USA
4. MIT-IBM Watson AI Lab, Cambridge, MA 02142, USA
5. Quest for Intelligence, Massachusetts Institute of Technology, Cambridge, MA 02139 USA
6. Neuro-X Institute, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland
7. Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN 55455 USA
8. The Program in Speech and Hearing Bioscience and Technology, Harvard University, Cambridge, MA 02138 USA

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10120732/

Reinforcement Learning

Papers:

- Glascher et al. (2011)
- Banino et al. (2018)
- Stachenfeld et al. (2017)
- Wang et al. (2018)
- Cross et al. (2021)

RL: Paper 1

States versus Rewards: Dissociable Neural Prediction Error Signals Underlying Model-Based and Model-Free Reinforcement Learning

Jan Gläscher • Nathaniel Daw • Peter Dayan • John P. O'Doherty

Open Archive • DOI: https://doi.org/10.1016/j.neuron.2010.04.016

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2895323/

RL: Paper 2

Letter | Published: 09 May 2018

Vector-based navigation using grid-like representations in artificial agents

Andrea Banino, Caswell Barry, Benigno Uria, Charles Blundell, Timothy Lillicrap, Piotr Mirowski, Alexander Pritzel, Martin J. Chadwick, Thomas Degris, Joseph Modayil, Greg Wayne, Hubert Soyer, Fabio Viola, Brian Zhang, Ross Goroshin, Neil Rabinowitz, Razvan Pascanu, Charlie Beattie, Stig Petersen, Amir Sadik, Stephen Gaffney, Helen King, Koray Kavukcuoglu, Demis Hassabis, ... Dharshan Kumaran

+ Show authors

https://www.nature.com/articles/s41586-018-0102-6

RL: Paper 3

Article | Published: 02 October 2017

The hippocampus as a predictive map

Kimberly L Stachenfeld, Matthew M Botvinick & Samuel J Gershman

Nature Neuroscience **20**, 1643–1653 (2017) | Cite this article

https://www.nature.com/articles/nn.4650

RL: Paper 4

Prefrontal cortex as a meta-reinforcement learning system

Jane X. Wang[1,5], Zeb Kurth-Nelson[1,2,5], Dharshan Kumaran[1,3], Dhruva Tirumala[1], Hubert Soyer[1], Joel Z. Leibo[1], Demis Hassabis[1,4] and Matthew Botvinick[1,4]*

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2895323/

RL: Paper 5

Article

Using deep reinforcement learning to reveal how the brain encodes abstract state-space representations in high-dimensional environments

Logan Cross [1 4], Jeff Cockburn [2], Yisong Yue [3], John P. O'Doherty [2]

https://www.sciencedirect.com/science/article/pii/S0896627320308990

Own Projects

Find a dataset (of brain activity) and pick a model / assessment technique and devise your own experiments to explore questions that interest you.

Group size: 1-3 people

Complete a research report / small journal article at the end of the semester outlining your findings, describing techniques used to analyse your data and the statistical or interpretability-based techniques used to assess your experimental questions.

Good Luck!