Computational Neuroanatomy and Neuroimaging

Instructor: Mallar Chakravarty, PhD
Time: Monday 1-4 pm
Room: Birks Building in room 004A
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Office Hours: By appointment

The goal of the unit is to introduce neuroimaging principles, their applications and their relationship to the understanding of basic principles of neuroscience and investigations of neuropsychiatric disorders. The students will be evaluated on their ability to critically appraise the articles that they are tasked to read and on their ability to integrate novel techniques into a grant application **that is removed from their primary area of research**. Technical knowledge on the basis of magnetic resonance imaging or imaging, in general, is not considered to be required for this course, but would be beneficial.

By the end of this course students should:

1) Understand the basis for experimental design in neuroimaging
2) Be able to successfully design their own experiments
3) Design experiments and understand the principles for appropriate computational tools for neuroimaging analyses.

Each class takes the form of a discussion of research articles. Review articles are provided for contextual purposes only.

Over the course of the semester:
Students need to pick **3 research articles** over the course of the semester and provide a 2 page short review (see end of syllabus for expectations).

Guidelines:

Page limit	2 pages
Content	A ½ page summary of article Followed by up to a **maximum** of 1½ pages of critique of strengths and weaknesses of the work
Submission	To be emailed to the professor before the beginning of the class where the article will be discussed Double check if you have clearly printed: ● Your name ● Student ID number ● Title for the article (on top of the page)

Before each class:
The student will email the professor 2 "big questions" regarding each paper (i.e. 4 questions in total per class). These are meant to help form a basis for discussion during each class. *Please submit these before 11 am on the day of the class so the instructor has time to amalgamate and review the questions.*

During each class:
The two papers assigned for each class will be discussed each week. Students are expected to have thoroughly read both papers.

1. *Paper 1:* One student is required to lead the discussion for one of the assigned papers.

Guidelines:

Time limit	40 minutes
Visual aids:	A powerpoint or google slide document would be beneficial to help the presentation and discussion of the paper
Other notes:	The student should demonstrate an understanding of the paper presented, the technical and scientific background. The student should also attempt to identify limitations and strengths of the paper.

2. *Paper 2:* The other paper assigned for the class will be **jointly presented by all students.** (All students are expected to have read the second paper prior to the class)

Guidelines:

Prep time	~ 30 minutes
Group formation	4 Groups will be formed by those who are present in the class
Assignment	Each group will be randomly assigned one section of the paper (e.g. introduction, methods, results, discussion etc.) Prepare a succinct summary of the paper and then present and discuss strengths and weaknesses of the paper with the rest of the class.

Mark Breakdown:

- Article Summaries: 20%
- Class presentation of manuscript: 20%
- Class participation based on preparedness, contributions, critical thinking, and leadership: 10% (Mark out of 10 awarded for each class)
- Written Grant Proposal: 25% (due October 29 at the beginning of class).
- Grant Oral Presentation: 25%

See the end of this document for the marking grid on class attendance and participation, summaries, and in-class presentations.

Class 1 (September 13, 2021): Image Segmentation
Lead Teaching Assistant: Swapna Premasiri (swapna.premasiri@gmail.com)

Review Articles:

- Iglesias JE and Sabuncu MR. *Multi-atlas segmentation of biomedical images: A survey.* Medical Image Analysis. 24 (1): 205-19, 2015
- Lerch JP, van der Kouwe AJ, Raznahan A, et al. *Studying neuroanatomy using MRI.* Nature Neuroscience. 20(3):314-26, 2017.

Articles:

- For student presentation:
  Fischl B, Salat DH, Busa E, et al. *Whole brain labelling: automatic segmentation of neuroanatomical structures in the human brain.* Neuron. 33(3): 341-55, 2002
- For group presentation:
  Coupe P, Manjon JV, Fonov V, et al. *Patch-based segmentation using expert priors: Application to hippocampus and ventricle segmentation.* NeuroImage. 54(2):940-54, 2011.

Class 2 (September 20, 2021): Cortical Thickness, Confounds of Movement, Structural Image Quality

Review Articles:

- Shaw P, Gogtay N, and Rapoport J. *Childhood psychiatric disorders as anomalies in neurodevelopmental trajectories.* Human Brain Mapping. 31(6): 917-25, 2010.

Articles:

- For student presentation:

Alexander-Bloch A, Clasen L, Stockman M, et al. *Subtle in-scanner motion biases automated measurement of brain anatomy from in vivo MRI.* Human Brain Mapping. 3(7): 2385-97, 2016.

- For group presentation:
  Rosen AFG, Roalf DR, Ruparel K, Blake J, et al. *Quantitative assessment of structural image quality.* NeuroImage. April 1 (169): 407-418, 2018

Class 3 (September 27, 2021): Diffusion MRI

Lead Teaching Assistant: Etienne St-Onge (Etienne.St-Onge@usherbrooke.ca)

Review Article:

- Jones DK, Knösche TR, and Turner R. *White matter integrity, fiber count, and other fallacies: the do's and don'ts of diffusion MRI.* NeuroImage. Jun(73): 239-54, 2013.

Articles:

- For student presentation:
  Baum GL, Roalf DR, Cook PA, et al. *The impact of in-scanner head motion on structural connectivity derived from diffusion MRI.* NeuroImage. Jun(173):275-86, 2018.
- For group presentation:
  Maier-Hein KH, Neher PF, Houde JC, et al. *The challenge of mapping the connectome based on diffusion tractography.* Nature Communications 8(1):1349, 2017.

Class 4 (October 4, 2021): Resting State fMRI and the Confounds of Movement

Lead Teaching Assistant: Gabriel Desrosiers-Gregoire (gabriel.desrosiers-gregoire@mail.mcgill.ca)

Review Article:

- Matthews M and Fair DA. *Functional brain connectivity and child psychopathology – overview and methodological considerations for investigators new to the field.* Journal of Child Psychology and Psychiatry. 56(4): 400-14, 2015.

Articles:

- For student presentation:
  Satterthwaite TD, Elliott MA, Gerraty RT, Ruparel K, Loughead J, Calkins ME, Eickhoff SB, Hakonarson H, Gur RC, Gur RE, Wolf DH. *An improved framework for confound regression and filtering for control of motion artifact in the preprocessing of resting-state functional connectivity data*. Neuroimage. 2013 Jan 1;64:240-56..
- For group presentation:
  Power JD, Plitt M, Laumann TO, et al. *Sources and implications of whole-brain fMRI signals in humans.* NeuroImage. Feb 1 (146): 609-25, 2017.

⚠️ **NO CLASS (October 11) – due to Thanksgiving**

Class 5 (October 18, 2021): Multi-Modal Brain Atlases

Lead Teaching Assistant: Aurelie Bussy (aureliee.bussy@gmail.com)

Review Article:

- Toga AW, Thompson PM, Mori S, et al. *Towards multi-modal atlases of the human brain.* Nature Reviews Neuroscience. 7(12):952—66, 2006.

Articles:

- For student presentation:
  Hawrylycz MJ, Lein ES, Guillozet-Bongaarts AL, et al. *An anatomically comprehensive atlas of the adult human transcriptome.* Nature. 489(7416):391-9, 2012.
- For group presentation:
  Glasser MF, Coalson TS, Robinson EC, et al. *A multi-modal parcellation of the human brain.* Nature. 536(7615):171-8, 2016.

Class 6 (October 25, 2021): Structural covariance

Review Article:

- Lerch JP, van der Kouwe AJ, Raznahan A, et al. *Studying neuroanatomy using MRI.* Nature Neuroscience. 20(3):314-26, 2017. (Note: This is also the review suggested in week 1)

Articles:

- For student presentation:
  Lerch JP, Worsley K, Shaw WP, et al. *Mapping neuroanatomical connections across cerebral cortex (MACACC) using cortical thickness from MRI*. NeuroImage. 31(3): 993-1003, 2006.
- For group presentation:
  Seidlitz J, Vasa F, Shinn M, et al. *Morphometric Similarity Networks Detect Microscale Cortical Organization and Predict Inter-Individual Cognitive Variation*. Neuron. 97 (1):231-247, 2018.

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Thursday, October 28, 2020

Deadline: Grant Submission Due!

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Class 7 (November 1, 2021): Quantitative MRI

Lead Teaching Assistant: Aurelie Bussy (aureliee.bussy@gmail.com)

Review Articles:

- Tardif CL, Gauthier CJ, Steele CJ, Bazin PL, Schäfer A, Schaefer A, Turner R, Villringer A. *Advanced MRI techniques to improve our understanding of experience-induced neuroplasticity.* Neuroimage. May 1(131):55-72, 2016. 10.1016/j.neuroimage.2015.08.047. Epub 2015 Aug 28.
- Weiskopf N, Mohammadi S, Lutti A, and Callaghan M. *Advances in MRI-based computational neuroanatomy: from morphometry to in vivo histology,* Current Opinion in Neurology. 28(4): 313-322, 2015.

Papers:

- For student presentation:
  Waehnert MD, Dinse J, Schäfer A, Geyer S, Bazin P-L, Turner R, and Tardif CL. *A subject-specific framework for in vivo myeloarchitectonic analysis using high resolution quantitative MRI.* NeuroImage. 125(January 15):94-107, 2016.
- For group presentation
  Marques JP, Khabipova D, and Gruetter R. *Studying cyto and myeloarchitecture of the human cortex at ultra-high field with quantitative imaging: R1, R2* and magnetic susceptibility.* 146(February 15):152-163, 2017.

⚠️ **NO CLASS November 8 - Society for Neuroscience**

Class 8 (November 15, 2021): Multi-Modal Integration

Lead Teaching Assistant: Gabriel Desrosiers-Gregoire (gabriel.desrosiers-gregoire@mail.mcgill.ca)

- For student presentation:
  Richiardi J, Altmann A, Milazzo AC, et al. *BRAIN NETWORKS.* Correlated gene expression supports synchronous activity in brain networks. Science. 348(6240):1241-4, 2015.
- For group presentation:
  Reardon PK, Seidlitz J, Vandekar S, et al. *Normative brain size variation and brain shape diversity in humans.* Science. 360(6394): 1222-1227, 2018.

Class 9 (November 22, 2021): Small Animal Imaging
Lead Teaching Assistants:
Lani Cupo (lani.r.cupo@gmail.com) and Lizette Herrera Portillo (lizette.herreraportillo@mail.mcgill.ca)

Review Articles:

- Francesca M, Cerri DH, Garin CM, Straathof M, van Tilborg GAF, Chakravarty MM, Dhenain M, et al. 2019. *Animal Functional Magnetic Resonance Imaging: Trends and Path Toward Standardization. Frontiers in Neuroinformatics 13: 78,* 2020.
- Nieman BJ, Bishop J, Dazai J, Bock NA, Lerch JP, Feintuch A, Chen XJ, Sled JG, Henkelman RM. *MR technology for biological studies in mice.* NMR in Biomedicine. 20(3): 291-303, 2007.

Articles:

- For student presentation:
  Grandjean, J., Schroeter, A., Batata, I., Rudin, M. *Optimization of anesthesia protocol for resting-state fMRI in mice based on differential effects of anesthetics on functional connectivity patterns*. NeuroImage, 102 Pt 2, 838–847, 2014.
- For group presentation:
  Ellegood J, Anagnostou E, …, Lerch JP. *Clustering autism: using neuroanatomical differences in 26 mouse models to gain insight into the heterogeneity*. Molecular Psychiatry 20(1): 118-125, 2015.

Class 10 (November 29 ,2021): Small animal imaging applications

Neonatal Imaging
Lead Teaching Assistants:
Lani Cupo (lani.r.cupo@gmail.com) and Lizette Herrera Portillo (lizette.herreraportillo@mail.mcgill.ca)

Review Article:

- Dan W and Zhang J. 2016. “Recent Progress in Magnetic Resonance Imaging of the Embryonic and Neonatal Mouse Brain.” *Frontiers in Neuroanatomy* 10 (March): 18.

Articles:

- For student presentation:
  Qiu LR, Fernandes DJ, Szulc-Lerch KU, Dazai J, Nieman BJ, Turnbull BJ, Foster JA, Palmert MR, and Lerch JP. 2018. *Mouse MRI shows brain areas relatively larger in males emerge before those larger in females.* Nature Communications 9 (1): 2615.

- For group presentation:
  Gass N, Becker R, Reinwald J, Cosa-Linan A, Sack M, Weber-Fahr W, Vollmayr B, Sartorius A. *Differences between ketamine's short-term and long-term effects on brain circuitry in depression.* 9(1):172, 2019.

Final Class (December 06, 2021): - Final class presentation!

Assignment marking rubric

Class participation (each class, mark provided out of 10)

- Attendance (/2)
- Were the 4 questions provided? (/2)
- Active Participation (/2)
- Provides commentary demonstrating knowledge of both papers (/2)
- Provides critical commentary useful to improving understanding and contextualizing the paper in the context of the literature (/2)

Article Reviews (3 for the term, mark provided out 10)

- Effective summary of the paper background (/2)
- Effective summary of the methods and main findings (/3)
- Effective criticism of methods, findings, and interpretations (/3)
- Grammar/Spelling (/2)

Article Presentation (1 for the term, mark provided out of 20; feedback given at the end of the class)

- Effective summary of the paper (/4)
- Useful background provided to help others understand methods and context (/4)
- Effective presentation of the main findings (/4)
- Effective criticism of methods, findings, and interpretations (/4)
- Quality presentation. Was it well-rehearsed, organized, and easy to understand (/4)