Canadian Symposium for Computational Neuroscience

OCTOBER 26-27, 2021

Campus Alberta
Neuroscience

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On behalf of the Computational Neuroscience Scientific Advisory Committee and Campus Alberta Neuroscience, welcome to the inaugural Canadian Symposium for Computational Neuroscience: The Mechanisms and Representations Behind Natural and Artificial Intelligences.

Understanding the workings of the brain – from single neurons to circuits to behavior - remains one of the greatest challenges in science. The brain inspires some of the most exciting (neuro)technologies of our time, from neuromorphic computing to smart machines and robots, and great leaps in understanding the brain have been made with rapid advances in large-scale recording technologies. With these advances, new computer algorithms, including deep-learning algorithms used in artificial intelligence (AI) and machine learning, are needed to make sense of the large volume of complex data (big data) produced by large-scale recording technologies.

Computational neuroscience is at the forefront of the development of solutions in understanding the massive amounts of data that are becoming available. These solutions will be found globally, nationally, and locally.

With that in mind, the Computational Neuroscience Scientific Advisory Committee - a committee facilitated by Campus Alberta Neuroscience of computational neuroscientists from the Universities of Alberta, Calgary, and Lethbridge - is proud to host its first Canadian Computational Neuroscience Symposium. The overarching goal of this virtual symposium is to bring together the national and international computational neuroscience community to share knowledge, research, and innovation, and form collaborative partnerships to advance this rapidly growing, interdisciplinary field.

We sincerely hope you find this symposium to be a unique and valuable learning and networking experience. We look forward to the opportunity to connect with the national and international neuroscience community to determine how we can all work together to take advantage of the opportunities presented to us through computational neuroscience.

COMPUTATIONAL NEUROSCIENCE SCIENTIFIC ADVISORY COMMITTEE

Aaron Gruber
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University of Calgary

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Campus Alberta Neuroscience

Adam Luoma
Campus Alberta Neuroscience

AGENDA DAY 1

Tuesday, October 26

12:30 – 12:45 PM

Opening Remarks
Jennifer Dotchin, Executive Director, Campus Alberta Neuroscience

12:45 – 2:00 PM

SESSION 1:
Neural and Network Dynamics Underlying Biological Computation
Chair: Wilten Nicola – University of Calgary

Modulation of synchronization in neural networks by a slowly varying ionic currents
Sue Ann Campbell – University of Waterloo

Cellular correlates of theta rhythms in biological computation
Frances Skinner – University of Toronto, Krembil Institute

Burst multiplexing and its role for the coordination of learning
Richard Naud – University of Ottawa

Question and Answer to follow presentations

2:00 – 2:45 PM

Networking Break & Lightning Talks

2:45 – 4:00 PM

SESSION 2:
Dimensionality Reduction and Population Dynamics in Neural Data
Chair: Majid Mohajerani – University of Lethbridge

The neural basis of a canonical attractor network
Adrien Peyrache – McGill University

Mapping the spatiotemporal dynamics of human brain responses with MEG/fMRI fusion method
Yalda Mohsenzadeh – Western University

Low-dimensional representation of neural oscillation dynamics
Karim Jerbi – University of Montreal

Question and Answer to follow presentations

4:15 – 5:15 PM

KEYNOTE PRESENTATION:
Geoffrey Hinton – Google Brain/University of Toronto/Vector Institute

AGENDA DAY 2

Wednesday, October 27

10:30 AM – 12:45 PM

Trainees: Workshop led by AMII

AMII

11 AM – 12:45 PM

PIs: Facilitated Collaboration Discussion and Networking

Canadian Brain Research Strategy/Scientific Advisory Committee

12:45 – 2:00 PM

SESSION 3:

Network Neuroscience Across Scales: From Single Cells to Behaviour

Chair: Joern Davidsen – University of Calgary

Bridging brain structure and function with network control theory
Emma Towlson – University of Calgary

Functional significance of brain network characteristics
Javeria Ali Hashmi – Dalhousie University

The brain in the social world: Integrating approaches from cognitive neuroscience and social network analysis
Carolyn Parkinson – University of California, Los Angeles

Question and Answer to follow presentations

2:00 – 2:45 PM **Networking Break & Lightning Talks**
Sponsored by AMII

2:45 – 4:00 PM

SESSION 4:

Information Encoding by Neural Ensembles

Chair: Aaron Gruber – University of Lethbridge
Moderator: Artur Luczak – University of Lethbridge

Aaron Gruber – University of Lethbridge

The functional specialization of visual cortex emerges from training parallel pathways with self-supervised predictive learning
Blake Richards – McGill University

Information coding by anterior cingulate cortex neurons versus ensembles
Jeremy Seamans – University of British Columbia

Question and Answer to follow presentations

4:15 – 5:15 PM **Awards Presentation & Closing Remarks**
Svenja Espenhahn, Project Manager, Campus Alberta Neuroscience

TALK #1:

Human EEG and Recurrent Neural Networks Exhibit Common Temporal Dynamics During Speech Recognition

Lukas Grasse, Saeedeh Hashemnia, Shweta Soni, and Matthew S. Tata

Canadian Centre for Behavioural Neuroscience, Department of Neuroscience, University of Lethbridge

Introduction:
Recent deep-learning artificial neural networks have shown remarkable success in understanding natural human speech. State-of-the-art networks currently use recurrent or dilated convolutional layers that enable the network to use a time-dependent feature space. The importance of time-dependent features in human cortical mechanisms of speech perception has also been of particular recent interest. It is possible that recurrent neural networks (RNNs) achieve their success by emulating aspects of cortical dynamics, albeit through very different computational mechanisms. In that case, we should observe commonalities between the temporal dynamics of deep-learning models, particularly in recurrent layers, and brain electrical activity recorded using electroencephalography (EEG) during speech perception.

Methods:
We presented the same sentences to both human listeners (5 native English speakers, 19 - 30 years of age) and the DeepSpeech RNN (open-source Mozilla implementation), and considered the temporal dynamics of the EEG and RNN units for identical sentences. We tested whether the recently discovered phenomenon of envelope phase tracking in human EEG is also evident in RNN hidden layers. We also predicted that the clustering of dissimilarity between model representations of pairs of stimuli would be similar for both RNN and EEG dynamics. We tested this prediction using Representational Similarity Analysis (RSA).

Results:
We found that the dynamics of both the recurrent layer of the network and human EEG signals exhibit speech envelope phase tracking with similar time lags. Using RSA, we also computed the representational distance matrices (RDMs) of brain and network responses to speech stimuli. The model RDMs increased in similarity to brain RDMs from early network layers to later ones, eventually peaking at the recurrent layer.

Conclusion:
These results suggest that the DeepSpeech RNN captures a representation of the temporal features of speech that is similar to the representation of speech by the human brain. These similarities are consistent with a hierarchical arrangement of the representation of speech features. This evidence gives a compelling reason to consider deep and recurrent neural networks as models of brain functions, despite profound differences in computational mechanisms.

TALK #2:

Using Machine Learning to Predict Intelligence in Children and Adolescents with ADHD

Brian Pho (1), Yalda Mohsenzadeh (1), Bobby Stojanoski (1,2)

1- Western University
2- Ontario Tech University

Introduction:
Childhood and adolescence represent a period of profound change in cognition, and the development of various cognitive abilities can be impaired by neurodevelopmental disorders such as attention-deficit/hyperactivity disorder (ADHD).

Methods:
Here, we apply machine learning to neuroimaging data to identify network patterns that underlie various aspects of intelligence in a large cohort of children and adolescents diagnosed with ADHD. We used a functional magnetic resonance imaging (fMRI) dataset (n=390) collected from children and adolescents (age 6-16) with ADHD provided by the Healthy Brain Network biobank. Individuals watched a 10-minute movie clip from 'Despicable Me' while fMRI data was collected, and measures of cognition (full scale IQ; FSIQ) using the Wechsler Intelligence Scale for Children (WISC-V) were also collected. After generating individual functional connectivity matrices, we applied a partial least squares (PLS) model to predict WISC scores from the functional connectivity profiles.

Results:
Across the full age range (6 – 16), we found that PLS could successfully model and predict FSIQ, VSI, VCI, and FRI with Pearson r=0.28-0.36 ($p<0.001$). When analyzing the model's weights for predicting FSIQ, we found positive weights for connections in the frontoparietal network in the right hemisphere, and negative weights for connections clustered in bilateral posterior sensory regions. Interestingly, when the dataset was binned by age, our PLS model could only predict FSIQ, VCI, and FRI in individuals aged 9-12 ($p<0.002$). We could not model any cognitive measure in individuals aged 6-9 and 12-16. These results have also been validated using Ridge models.

Conclusions:
We can successfully predict intelligence from movie-watching fMRI in atypically developing children and adolescents using PLS and Ridge models. Our results suggest different sets of connections used for predicting different components of intelligence in different age bins. Specifically, the model emphasized frontoparietal connections and deemphasized bilateral sensory connections when predicting FSIQ in individuals aged 6-16, supporting the hypothesis that differences in the frontoparietal network are more predictive of intelligence than differences in sensory areas. We also found that connectivity profiles appear to follow an inverted U-shape for cognitive development as our models could not predict cognition in individuals aged 6-9 and 12-16 but could in ages 9-12.

TALK #3:

Predicting pediatric anxiety from the temporal pole using neural responses to emotional faces

Jeffrey Sawalha (1), Muhammed Yousefnezhad (1,2) Alessandro M. Selvitella (3) Bo Cao (1) Andrew J. Greenshaw (1) Russell Greiner (2)

1- University of Alberta, Department of Psychiatry
2- University of Alberta, Department of Computer Science
3- Purdue University, Department of Mathematical Sciences

Introductions:
A prominent cognitive aspect of anxiety is dysregulation of emotional interpretation of facial expressions, associated with neural activity from the amygdala and prefrontal cortex.

Methods:
We report machine learning analysis of fMRI results supporting a key role for a third area, the temporal pole (TP) for childhood anxiety in this context. This finding is based on differential fMRI responses to emotional faces (angry versus fearful faces) in children with one or more of generalized anxiety, separation anxiety, and social phobia (n = 22) compared with matched controls (n = 23).

Results & Conclusions:
In our machine learning (Adaptive Boosting) model, the right TP distinguished anxious from control children (accuracy = 81%). Involvement of the TP as significant for neurocognitive aspects of pediatric anxiety is a novel finding worthy of further investigation.

TALK #4:

A network neuroscience approach to understanding Developmental Topographical Disorientation

Mahsa Faryadras (1), Ford Burles (2), Giuseppe Iaria (2,3), Joern Davidsen (1,3)

(1) Complexity Science Group, Department of Physics and Astronomy, University of Calgary
(2) NeuroLab, Department of Psychology, University of Calgary
(3) Hotchkiss Brain Institute, University of Calgary

Introduction:
Developmental Topographical Disorientation (DTD) is a neurological condition wherein individuals are unable to orient themselves and may, in some extreme cases, get lost even within their own homes. This lifelong navigational impairment is present in the absence of other neurological disorders or acquired brain damage, with intact sensory and intellectual functions. It is hypothesized that DTD is associated with the inability to generate a cognitive map, a mental representation of the environment which is critical for orientation. To date, the underlying mechanism behind this condition is still unknown. Network neuroscience, a graph theory approach for identifying how different brain areas interact and communicate, has brought new insights into our understanding of different brain disorders.

Methods:
Here, we compare functional brain networks of DTD diagnosed individuals against healthy controls (HC), to understand if and how a DTD functional brain network differs from the control. To this end, resting state fMRI for 21 HC and 19 individuals diagnosed with DTD were used to compute group-level functional brain networks. These networks were analyzed at the levels of the whole connectome, resting state networks (RSNs), and nodes.

Results:
We show greater connectivity in the DTD group on average, with no significant difference between the two groups over all global network properties. We found the same RSNs in both the DTD and HC groups, with no significant alteration in their intra-RSN connectivities.

Conclusions:
This is consistent with the observation that general cognitive abilities in individuals with DTD are preserved. Interestingly, communication between some RSNs were significantly enhanced in the DTD group, suggesting a compensating mechanism in these individuals to navigate their environment. Similarly, we interpret increased connectivity in some ROIs as a compensatory mechanism. For example, the right superior frontal sulcus is associated with both an increased load in visual working memory recognition as well as greater uncertainty while decision making. Despite contextualizing a set of candidate ROIs, we believe that the impairment in the complex ability of orientation is not reducible to only a circumscribed set of regions. Instead, our results suggest that this functional deficit is more related to higher level network effects.

Lightning Talks

Theme 3: Network Neuroscience Across Scales: From Single Cells to Behavior

TALK #5:

Investigating Differential Patterns of Hippocampal Connectivity in Posttraumatic Stress Disorder (PTSD) via fMRI

Mohammad Chaposhloo (1), Saurabh Bhaskar Shaw (2), Andrew A. Nicholson (3), Suzanna Becker (1)

1- Department of Psychology, Neuroscience, and Behavior, McMaster University
2- Department of Psychiatry, Western University
3- Department of Psychaiatry and Behavioral Neuroscience, McMaster University

Introduction:
Many neurobiological models of Post-traumatic Stress Disorder (PTSD) identify the hippocampus as a core brain region underlying PTSD symptoms. However, not all studies have reported altered hippocampal connectivity in PTSD, possibly because few studies have differentially assessed the connectivity of the anterior versus posterior sub-regions. Between these two hippocampal subregions, the anterior portion is of greater relevance to PTSD, given its association with fear and anxiety circuitry.

Methods:
Here, we examined resting-state functional connectivity profiles of the anterior and posterior hippocampus in a publicly available resting-state fMRI data set collected from 31 male Vietnam War veterans diagnosed with PTSD compared to 29 healthy, combat-exposed controls.

Results:
Our analysis revealed the anterior hippocampus as a critical locus of dysfunction in the context of PTSD. Specifically, the PTSD group exhibited increased functional connectivity between the anterior hippocampus and affective brain regions including the anterior and posterior insula, orbitofrontal cortex, and the right temporal pole.

Conclusion:
Our findings emphasize the potential role of hippocampal subregions to serve as biomarkers of PTSD.

TALK #6:

Embedded Chimera: from individual chaotic activity to a collective chimera

Maria Masoliver, Wilten Nicola and Joern Davidsen

University of Calgary

Introduction:
It has been experimentally verified that synchronization and partial synchronization of brain activity play an important role in the pathogenesis of several neurological diseases, such as Parkinson's disease, Alzheimer's disease and essential tremor (among others) as well as in normal functioning brain circuits (e.g. during memory consolidation). However, the fundamental principles and constraints that govern the intricate timing and specificity of the time-evolving patterns of partial synchrony are not well understood.

Here we aim to relate the mathematical concept of the chimera state, where synchrony and asynchrony coexist, to partial synchronization in the brain. So far, chimera states have been investigated through bottom-up approaches using simple mathematical models. However, these simple models are not directly applicable to real biological systems (e.g. brain regions), which are extraordinarily complex networks of coupled dynamical systems. Yet, there has been some initial work relating chimera states to brain-related disorders such as epileptic seizures, Parkinson's and schizophrenia, as well as, in the normal operating regime of circuits like the hippocampus.

Methods:
Here we initiate a novel approach by training the synaptic connections of an artificial recurrent neural network to display a chimera state by using the novel machine learning technique FORCE method, which allows to create networks that mimic complex dynamics.

Results & Conclusions:
By using it, we establish how chimera states can in principle emerge at the mesoscopic and macroscopic level in brain circuits. We show that their emergence is quite generic at the meso and macroscale suggesting their general relevance in neuroscience in both pathological and healthy circuits.

Lightning Talks

Theme 4: Information Encoding by Neural Ensembles

TALK #7:

Modelling the neural code in large populations of correlated neurons

Sacha Sokoloski (1), Amir Aschner (2), Ruben Coen-Cagli (3)

1- University of Tübingen
2- The Hospital for Sick Children
3- Albert Einstein College of Medicine

Introduction:
Neurons respond selectively to stimuli, and thereby define a code that associates stimuli with the response patterns of neural populations. Certain correlations within population responses (noise correlations) are known to significantly impact the information content of the neural code, especially in large populations. Understanding the neural code thus requires response models that can be fit to large-scale neural recordings, capture noise correlations, and quantify the coding properties of modelled populations. In this talk we present a novel class of response model based on mixture models and exponential families that satisfies these requirements.

Methods:
We validate considered models on two sets of electrophysiological recordings from macaque primary visual cortex (V1) responding to oriented gratings, one of 43 neurons from an awake macaque, and one of 70 neurons from an anaesthetized macaque. We use 10-fold cross-validation to evaluate both how well relevant models capture the statistics of V1 population responses (encoding), and how well these models support extracting stimulus information from these responses (decoding). We compare our model to a number of alternatives, including encoders based on factor analysis, and decoders based on artificial neural networks.

Results:
We derive an algorithm for fitting the model to data using Expectation Maximization (EM), and show that it captures the statistics of neural responses at least as well as factor analysis. We show how to turn our model into a Bayesian decoder, and that its decoding performance is competitive with other more computationally demanding decoding methods such as artificial neural networks. Finally, we show that our model has valuable analytic properties, and affords a closed-form expression for the Fisher information of the model (which is a widely-used tool for measuring the information capacity of neural populations), and is compatible with the Bayesian theories of neural coding known as probabilistic population codes (PPCs).

Conclusion:
Our models simultaneously capture the response statistics of large populations of neurons, and their coding properties. This could allow researchers to quantitatively validate the predictions of neural coding theories against both large-scale neural recordings and cognitive performance.

TALK #8:

Prediction of new diffusion MRI data is feasible using robust machine learning algorithms for multi-shell HARDI in a clinical setting

Cayden Murray BSc, Olayinka Oladosu BSc, Yunyan Zhang MD PhD

Department of Neuroscience, Radiology and Clinical Neurosciences, University of Calgary.

Introduction:
The advent of higher angular resolution diffusion imaging (HARDI) provides a unique opportunity to examine sub-voxel measures of tissue microstructure. However, HARDI analysis requires acquisition of multiple copies of diffusion MRI (multi-shell HARDI), which is time consuming and not always practical in a clinical setting. The goal of this study was to develop robust machine learning algorithms to predict new diffusion data from clinically feasible diffusion MRI.

Methods:
The development included 2 algorithms: multi-layer perceptron (MLP) and convolutional neural network (CNN). Both followed a voxel-based approach for model training (70%), validation (15%), and testing (15%) using 2 types of data: 1) multi-shell HARDI of 6 healthy subjects from the Human Connectome Project (HCP); and 2) local 2-shell diffusion MRI from 6 patients with multiple sclerosis (MS). The HCP data were used for model refinement using a limited grid search method, and local data for testing real-world utility. Subsequently, 2 HARDI metrics: orientation dispersion index (ODI) and neurite density index (NDI), were calculated based on the Neurite Orientation Dispersion and Distribution Imaging (NODDI) approach for both predicted and original HARDI data, and their outcomes were compared using 2 quantitative measures: PSNR) and SSIM.

Results & Conclusions
Results showed that both models provided robust predictions, which yielded highly similar ODI and NDI to the original indices. The CNN outperformed MLP with the HCP data on both PSNR ($p<0.001$) and SSIM ($p\leq0.01$), yet they performed similarly for the local MS data ($p>0.05$). Overall, using robust machine learning algorithms, it is possible to enable multi-shell HARDI in clinical practice.

TALK #9:

Prenatal Maternal Stress during the COVID19 Pandemic and Sub-Cortical Brain Volumes in 3-Month-Old Infants

Ti-Amo Deruz Richards, Gerald Giesbrecht, Lianne Tomfohr-Madsen, Li Wang, Catherine Lebel

University of Calgary
University of North Carolina

Introduction:
Pregnant people have had higher rates of stress, depression, and anxiety during the COVID-19 pandemic. Previous studies of natural disasters have shown changes in subcortical limbic volumes in infants whose mothers were exposed to stressors during natural disasters during pregnancy; therefore pandemic-related distress may be associated with altered brain volumes in infants born during the pandemic. The purpose of this study was to use magnetic resonance imaging (MRI) to examine how psychological distress experienced by pregnant individuals during the COVID-19 pandemic is associated with infant brain grey matter volumes.

Methods:
As part of a larger study (Pregnancy During the Covid-19 Pandemic), women completed the 10-item Perceived Stress Scale (PSS) during pregnancy at a mean gestational age of 29.8 weeks (6.9 +/- st. dev). T1- and T2-weighted magnetic resonance imaging (MRI) was collected on 67 infants aged 3 months (45M/22F), on a GE MR750w scanner at the Alberta Children's Hospital. Images were segmented using iBEAT to provide amygdala, caudate, and hippocampal volumes for each hemisphere. We tested for a relationship between infant brain volumes and perceived stress scores using multiple regression and an alpha level of < 0.05. Multiple regression was done in SPSS, with sex, household income, maternal education and total intra-cranial volume included as covariates.

Results:
Subcortical volumes in the right caudate were significantly negatively related to perceived stress scores (B= -8.063, beta=-0.196; $p = 0.048$). Mothers who reported higher prenatal stress were more likely to have infants with smaller caudate volumes. Perceived stress scores were not significantly related to other subcortical volumes in this sample.

TALK #10:

The Use of Machine Learning Models to Classify Proprioceptive Impairments after Stroke based on Robotic Assessments

Delowar Hossain (1), Stephen H. Scott (2), Tyler Cluff (3), and Sean P. Dukelow (1)

1- Department of Clinical Neuroscience, Cumming School of Medicine, University of Calgary
2- Department of Biomedical and Molecular Sciences, Queen's University
3- Faculty of Kinesiology, University of Calgary

Introduction:
Proprioception is the sense of limb position and movement. It is commonly impaired after stroke. Members of our team have developed robotic tools to precisely measure impaired position sense. The purpose of this study was to investigate the ability of machine learning and deep learning techniques to classify individuals as to whether they had a stroke or not based on performance in a robotic arm position matching (APM) task.

Methods:
Four hundred and twenty-nine participants with neuroimaging confirmed stroke (days post-stroke <35) and 465 healthy control participants were recruited. Participants performed an APM task in the Kinarm exoskeleton robot to assess upper limb position sense. The task produced 12 parameters to quantify proprioception. We first examined stroke participants performance on individual parameters to determine if they fell outside of the 95% range of control values. Then, we applied five machine learning models (i.e., Logistic Regression, Decision Tree, Random Forest, Random Forest with Hyperparameter Tuning, and Support Vector Machine) and one deep learning model (i.e., Deep Neural Network) to classify participants as stroke or healthy control based only on the results of their robotic assessments, using 10-fold cross-validation approach.

Results:
The average impairment rate across individual parameters was 39%. The average classification accuracy of machine learning and deep learning models was 85%. All machine learning models displayed similar classification accuracy; however, Random Forest with Hyperparameter Tuning model had the highest numerical accuracy (86.4%). The average area under the curve (AUC) value for the receiver operating characteristics (ROC) curve was 0.908, where the Logistic Regression model had the highest value (0.93).

Conclusions:
Our machine learning and deep learning models classified more subjects correctly as stroke or control than classification based on individual parameters. Classification accuracy across machine learning and deep learning models was similar. Machine and deep learning methods may provide opportunities to better understand proprioceptive impairments after stroke.

TALK #11:

Modeling progressive neurodegeneration in silico with deep artificial neural networks

Anup Tuladhar, Jasmine A. Moore, Zahinoor Ismail, Nils D. Forkert

University of Calgary

Introduction:
The hierarchical organization of deep convolutional neural networks (DCNNs), inspired by the visual cortex, make them suitable as brain-like models of higher order visual processing. However, their potential as in silico models of neural diseases has been largely neglected. In this work, we used DCNNs to simulate neurodegeneration in silico. We mimicked synaptic injury by severing connections between the neurons in the DCNN and measured its impact on visual object recognition.

Methods:
We used the VGG-19 DCNN, which is a top-rated DCNN for predicting neural responses in primate visual cortex. We trained the network on the CIFAR-100 image dataset, which contains images of objects from 100 classes (e.g. roses, butterflies, bicycles) that are organized into 20 categorical superclasses (e.g. flowers, insects, vehicles). Importantly, the networks were only given information on the object class labels and no information about an object's categorical superclass.
The trained DCNNs were injured by randomly setting x percent of the network weights to zero, effectively severing the connections between neurons. Progressive neurodegeneration was simulated by repeatedly injuring a model at 0.1% increments, such that damage is cumulative. A total of 25 networks were trained and injured.

Results:
Injured DCNN's object categorization performance decreased with increasing injury. By 30% injury, the network's performance was on-par with random chance (1%). The percentage of misclassified objects that were still within the same categorical superclass (e.g. a rose misclassified as another type of flower) was stable and similar to the uninjured DCNN for the first 1.3% of injury. After 1.3% injury, the networks misclassified objects into the wrong superclass more often than the uninjured DCNN, reaching chance level (5%) at 25% injury.

Conclusions:
We presented an in silico model of neurodegeneration using DCNNs. This work is the first attempt to use DCNNs as an model of neurodegeneration with promising results. Further work is needed to investigate the biological resemblance of DCNNs in this context. As deep neural network models continue to approach human level performance in many complex tasks, this paradigm of in silico neurodegeneration could be applied to other task such as language processing, memory and decision making.

TALK #12:

The propagation of localized REM sleep in the mouse cortex

Davor Curic (1), Surjeet Singh (2), Majid Mohajerani (2), Joern Davidsen (1)

1- University of Calgary
2- University of Lethbridge

Introduction:
Neuronal activity organizes into collective dynamics with many frequencies and rhythms. In particular, sleep dynamics can be described as a switching between two broad states often characterized by the presence or absence of certain frequencies; rapid eye movement sleep (REM), where-in neuronal desynchronization produces high theta (5 – 9 Hz) power reminiscent of waking behaviour, and non-REM, which is associated with high delta (0.5 - 2 Hz) power thought to originate from widespread neuronal synchronization. While the exact function of the REM and non-REM states is not yet fully understood, research has suggested a role in the transfer of short-term memories from the hippocampus to long term storage in the cortex. Up until recently, the prevailing theory has been that REM and non-REM constituted global brain states. However, this assumption has been found to be incorrect – REM and nREM are instead localized phenomena. The crucial next then is to understand how these localized areas of neuronal de/synchronization evolve in both space and time in the brain.

Methods:
In this work, we tackle this problem by analyzing the statistical properties of the spatio-temporal propagation of signals associated with REM, gathered from high-resolution optical voltage sensitive dye imaging data at the mesoscale of the mouse cortex. To do so we utilize wavelet methods to analyze the time-dependent power in the theta band against the power in the delta band, for each pixel corresponding to an area of the cortex. By taking high values of this signal as a proxy for neural desynchronization we can generate so-called desynchronization cascades. We then study the spreading properties of these cascades not only on the field of view but also the functional network generated via pair-wise correlation analysis between pixels.

Results & Conclusions:
We show both approaches reveal the spreading of desynchronization follows scale-free statistics. This suggests that sleep is indeed not comprised by a global REM/non-REM state. Instead, a balance of both synchronized and desynchronized neural activity is simultaneously maintained. Understanding how these states evolve spatio-temporally may be an important aspect of understanding sensory disconnection during REM, and elucidate potential mechanisms for long-term memory formation.

Biographies of Speakers

KEYNOTE

Geoffrey Hinton

Google Brain
University of Toronto
Vector Institute

Dr. Geoffrey Hinton is an internationally recognized researcher for his work on artificial neural networks. He currently holds positions at the University of Toronto as a professor emeritus, Google as a VP and Engineering Fellow, and the chief scientific advisor for the VECTOR institute. Dr. Hinton's research has been extremely influential with his research leading to many distinctions including honorary doctorates from the universities of Sherbrooke, Sussex, and Edinburgh. Alongside Drs. Yann LeCun and Yoshua Benjio, Dr. Hinton received the 2019 Turing award for conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing.

Sue Ann Campbell

University of Waterloo

Sue Ann Campbell received BMath from the University of Waterloo her PhD from Cornell University. She is currently a Professor of Applied Mathematics and University Research Chair at the University of Waterloo. She has served on the editorial boards of several journals including J. Nonlinear Science, J. Matheamtical Neuroscience and SIAM J. Applied Math. Her research interests include dynamical systems, delay differential equations and their application to problems in computational neuroscience.

Frances Skinner

University of Toronto, Krembil Institute

Frances Skinner is a Senior Scientist at the Krembil Research Institute and a Professor at the University of Toronto. She graduated from the University of Waterloo (B.Math.) and Toronto (M.A.Sc., Ph.D.) and did 4 years of postdoctoral work in Boston and California. She enjoys collaborative work and is interested in determining cellular-based mechanisms underlying the dynamic output of neuronal networks in normal and pathological states. She is particularly interested in advancing our understanding by creating win-win scenarios with the plethora of data and theoretical and experimental approaches available today.

Biographies of Speakers

Richard Naud

University of Ottawa

Richard is originally from Montreal where he studied Physics at McGill University. He then moved to Switzerland to do his Ph. D. in computational neuroscience in the lab of Wulfram Gerstner. After postdoctoral research in Cambridge (UK) and Berlin, he has started his lab at the University of Ottawa. His work focuses on the information processing capabilities of cortical neural networks.

Adrien Peyrache

McGill University

Adrien Peyrache graduated in Physics and Chemistry (MSc, ESPCI - Paris Science et Lettres) and in Cognitive Science (MSc, Ecole Normale Superieure). His doctoral work at the College de France focused on the neural basis of sleep-dependent learning. He then moved to the laboratory of Gyorgy Buzsaki at New York University where he characterized the organization of neuronal population activity in the head-direction network. Sicne 2016, he is an assistant at the Montreal Neurological Institute, Mcgill University and holds the Canadian Research Chair (Tier 2) in Systems Neuroscience.

Yalda Mohsenzadeh

Western University

Yalda Mohsenzadeh is an Assistant Professor in the Department of Computer Science and a core member of the Brain and Mind Institute at Western University, London, ON, Canada. She is also a faculty affiliate with Vector Institute for Artificial Intelligence, Toronto, ON, Canada. Before joining Western, she was a postdoctoral associate in the Computer Science and Artificial Intelligence Lab (CSAIL) and McGovern Institute for Brain Research at MIT, Cambridge, MA, USA. Prior to that, she was a postdoctoral fellow in the Center for Vision Research at York University, Toronto, ON, Canada. Yalda received her PhD in statistical machine learning in 2014 from Amirkabir University of Technology, Tehran, Iran. Her research is interdisciplinary, spanning machine learning, computer vision and their application in cognitive neuroscience and neuroimaging with a successful track record of collaboration with industry sectors.

Biographies of Speakers

Karim Jerbi

University of Montreal

Karim Jerbi holds a Canada Research Chair in Computational Neuroscience and Cognitive Neuroimaging at the University of Montreal. The multidisciplinary research conducted in his laboratory seeks to advance our understanding of the role of large-scale neural networks in healthy cognition, their alteration across states of consciousness and breakdown in brain disorders. To this end, his research combines magnetoencephalography (MEG), scalp- and intracranial electroencephalography (EEG) with advanced signal processing and data analytics including machine learning. Dr Jerbi currently heads the UNIQUE center, a Quebec-wide Neuro-AI research cluster (Unifying Neuroscience and AI in Quebec) which seeks to bridge biological and artificial intelligence research.

Emma Towlson

University of Calgary

Dr. Emma Towlson is an Assistant Professor at the University of Calgary, with appointments in the Department of Computer Science, the Department of Physics and Astronomy, the Hotchkiss Brain Institute, and Alberta Children’s Hospital Research Institute. She is a network neuroscientist who believes that complex systems science is at the heart of understanding our interconnected world and the organisms that share it. Emma completed her postdoctoral training at the Center for Complex Network Research at Northeastern University, received her PhD from the University of Cambridge (2015), and hold a Masters in Mathematics and Physics from the University of Warwick (2011).

Javeria Ali Hashmi

Dalhousie University

Dr.Hashmi is an Assistant Professor/Canada Research Chair at Dalhousie University, Canada. She trained as a neuroimager and pain scientist at the University of Toronto, Northwestern University (Chicago) and Harvard Medical School. Her research uses network models to study brain network characteristics that mediate pain perception.

Biographies of Speakers

Carolyn Parkinson

University of California, Los Angeles

Carolyn Parkinson is an Assistant Professor in the Department of Psychology, faculty at the Brain Research Institute, and the Wendell Jeffrey and Bernice Wenzel Term Endowed Chair in Cognitive Neuroscience at the University of California, Los Angeles (UCLA), where she directs the UCLA Computational Social Neuroscience Lab. She obtained her B.Sc. in Psychology from McGill University, then obtained her Ph.D. in Cognitive Neuroscience from Dartmouth College. Her research examines how the human brain represents, navigates, and is shaped by the structure of its social environment by integrating approaches from cognitive neuroscience, social network analysis, and social psychology.

Aaron Gruber

University of Lethbridge

Dr. Aaron Gruber is a member of the Canadian Center of Behavioral Neuroscience at the University of Lethbridge. Receiving a masters and PhD from Northwestern, Dr. Gruber is fascinated by reward systems, in specific dopamine's effect on behavior. Through this, he researches neurobiology of decision making, and models psychiatric illness.

Blake Richards

McGill University

Blake Richards is an Assistant Professor in the School of Computer Science and the Montreal Neurological Institute at McGill University and a Core Faculty Member at Mila, The Quebec Artificial Intelligence Institute. He was the 2019 Canadian Association for Neuroscience Young Investigator Award Recipient, and one of the Canadian Institute for Advanced Research (CIFAR) Canada AI Chairs announced in 2018. His lab's research focuses on the intersection between neuroscience and artificial intelligence, seeking general principles of learning that apply to both natural and artificial agents.

Jeremy Seamans

University of British Columbia

I received my PhD from UBC and did a PDF in computational neurobiology at the Salk Institute. I have been a professor at UBC since 2006. My interest lies in understanding the functions of the anterior cingulate cortex and how these functions are accomplished at a cellular level. Experimental approaches include tetrode recordings in behaving rats, optogenetics and computational modeling.

NOTES

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