Models of Consciousness 2022

A conference on mathematical approaches in the scientific study of consciousness

Frances C. Arrillaga Alumni Center, Stanford University CA USA
September 5-9, 2022

Association for Mathematical Consciousness Science

Sponsors and organising institutions

Association for Mathematical Consciousness Science

FQXi
FOUNDATIONAL QUESTIONS INSTITUTE

OMCAN
Oxford Mathematics of Consciousness and Applications Network

UNIVERSITY OF OXFORD

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

RUB

SAINT ANSELM COLLEGE
1889

mC Mp Munich Center for Mathematical Philosophy

Center for the Explanation of Consciousness

PROGRAMME

Table of Contents

Welcome

Thank you for being part of the third instalment of the Models of Consciousness conference series (MoC3-2022). As we push further into the third decade of the 21st century, mathematical approaches in the scientific study of consciousness are bringing new insights and opportunities for disruptive scientific advancement. The introduction of mathematics into the research program allows long established methodologies, used to great effect in fields such as theoretical physics and computer science, to become accessible to the scientific study of consciousness. The use of mathematical modelling to translate systems, hypotheses and phenomena into the mathematical domain ignites the modelling cycle and allows assertions, hypothesise and ideas to be objectively tested against our scientific knowledge of consciousness, the brain, mathematics and physics. MoC3 seeks to stimulate and facilitate the continuing development of Mathematical Consciousness Science, both at the level of individual models and theories and in terms of the objective scientific processes and methodologies that act upon them to accelerate advancement of the field.

MoC3 builds on the success of the inaugural MoC conference, held at the University of Oxford in September 2019, and MoC2, held online in September 2021.
By kind invitation of the Center for the Explanation of Consciousness at Stanford, MoC3 takes place in the beautiful Alumni Center of Stanford University. Stanford is also home to the Stanford Encyclopedia of Philosophy, which is an invaluable source for historical references related to consciousness and philosophy.
Welcome to Stanford!

Website at: https://amcs-community.org/events/moc-3-2022

The conference team

Organisers*

Dr Jonathan Mason
Oxford Mathematics of Consciousness and Applications Network (OMCAN)
Mathematical Institute
University of Oxford
UK

Dr Johannes Kleiner
Munich Center for Mathematical Philosophy
Ludwig Maximilian University of Munich
Germany

Dr Robert Prentner
Munich Center for Mathematical Philosophy
Ludwig Maximilian University of Munich
Germany

Dr Robin Lorenz
Cambridge Quantum
Oxford
UK

Dr Wanja Wiese
Institute for Philosophy II
Ruhr University Bochum
Germany

Advisory board

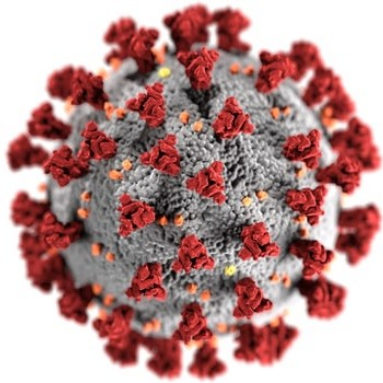
Prof. Ian Durham
Department of Physics
Saint Anselm College
NH USA

Prof. Yakov Kremnitzer
Oxford Mathematics of Consciousness and Applications Network (OMCAN)
Mathematical Institute
University of Oxford
UK

Prof. Paul Skokowski
Center for the Explanation of Consciousness
CSLI
University of Stanford
USA

*The advisory board gratefully acknowledges the work and effort of all the organisers and gives particular thanks to Dr Mason who lead the work.

Covid 19



We want everyone to have a healthy conference. Here are some of the measures in place to help us all keep healthy.

- The conference welcome desk has a supply of rapid antigen tests for participants at the conference to use when they think it helpful to do so. Participants may like to take a test on first arrival.
- Disposable face masks are available at the conference welcome desk for those who want to use them. The Stanford Guest House also provides face masks for use in public areas at the Guest House.
- The main social programme is all outdoors including the excursion on Monday 5th and the drinks reception and conference dinner on Thursday 8th September.
- The lecture rooms and discussion rooms all have movable seating and participants are welcome to move the seating to create more space.
- If you become unwell with Covid while at the conference then the AV system allows speakers to present their talks from their room at the Stanford Guest House over Zoom to avoid missing out on presenting.

Stanford Guest House

Many participants will be staying at the Stanford Guest House, (2575 Sand Hill Road, Menlo Park, CA 94025). Complementary services include: Wi-Fi and Eduroam access; overnight parking; tea and coffee 24 hrs a day; fitness room; front desk staffed 24 hrs a day; disposable face masks. Details about breakfast options near the Guest House and at Arbuckle's on campus, and transport to the Stanford Campus, are available on page 16. If going elsewhere on campus for breakfast, please check the opening times.

https://rde.stanford.edu/hospitality/stanford-guest-house
https://rde.stanford.edu/stanford-guest-house/dining
https://rde.stanford.edu/stanford-guest-house/transportation

Rooms have been booked and paid for by the conference on behalf of the invited speakers. Participants, other than invited speakers, should have received the group booking code (MCON22) by email for making their room booking arrangements. The contact person at the Guest House is Richard Rivas:

rrivas2@stanford.edu

We hope everyone has a comfortable stay!

Excursion

Here are some details for invited speakers and those signed up for the excursion on **Monday September 5th**.

A Royal Coach Tours hire bus will pickup participants from two locations:

- 9:30am - Pickup from the Stanford Guest House;
- 9:45am - Pickup from Galvez St Turnaround (On Galvez St at Serra Mall Stanford, CA 94305).

Participants are free to join one of two groups:

- Group 1 - Montara Mountain hike, **10.5 miles**, 4.5 hours;
- Group 2 - A short walk (1.5 miles) and time at the beach.

A selection of bagged lunch options will be made available to all participants along with bottled water. Each group will have a designated guide. The hire bus pickup to return to Stanford is at:

- 4:45pm - Half Moon Bay Downtown (CA 94019)

Please bring sunscreen, hat and sensible shoes; particularly group 1.

Conference dinner and drinks reception

Thursday September 8th includes a number of special events. At various points during the day the conference will be joined by a small number of specially invited guests from organisations such as foundations and members of the Silicon Valley community.

Consciousness and AI
The morning programme includes a session around the theme of consciousness and AI.

Oxford MCS Showcase
The afternoon includes an Oxford lead Mathematical Consciousness Science Showcase event organised with the special guests in mind.

Drinks reception
We are delighted to invite the whole conference to a drinks reception organised at McColl Plaza, outside the conference centre, at 5pm. **Please join everyone for drinks.**

Conference Dinner
At 6pm, following the drinks reception, invited speakers, special guests and participants who have paid will come together for the conference dinner, also at McColl Plaza. The dinner is a buffet so that people can choose what they like.

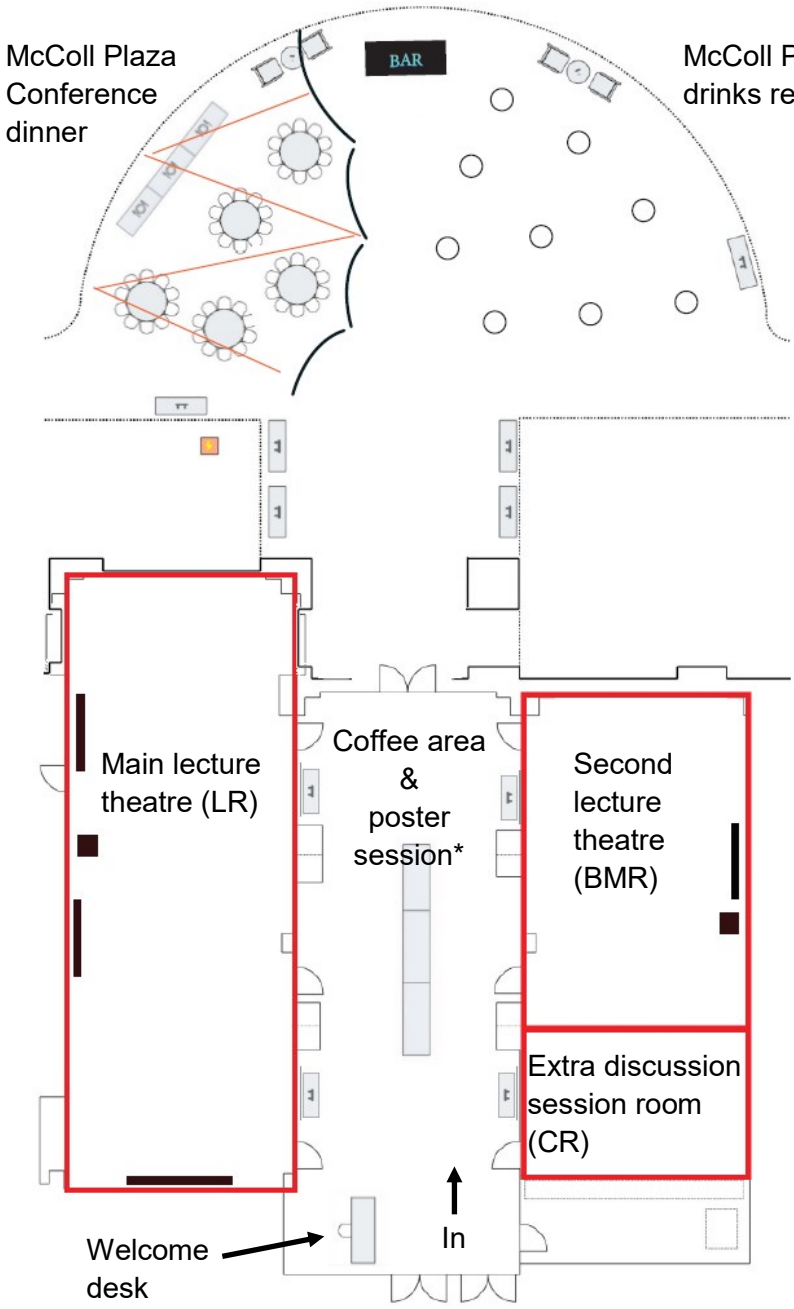
Main Course

Chicken Picatta with Grilled Lemons and Capers (no Gluten)
Butternut Squash Ravioli in a Sage Asiago Cream Sauce (Vegetarian)
Stuffed Roasted Peppers filled with Eggplant, Squash, Rice, and Basil (Vegan, no Gluten)
Baby Spinach Salad with Marinated White Button Mushrooms, Frisee, and a Creamy Lemon Dressing (Vegetarian, no Gluten)
Seasonal Roasted Vegetable Medley (Vegan, no Gluten)
Wild Rice Pilaf, served with Bread Rolls and Butter, Gluten Free Bread Rolls and Butter

Dessert

Mini Tartlets - Fruit, or Chocolate Cream; Mini Cheesecake Bites

Building plan



Frances C. Arrillaga Alumni Center,
326 Galvez Street Stanford, CA 94305-6105, USA

Coffee, tea and lunch

Coffee and tea breaks

Coffee and tea are provided by the conference twice a day in the lobby outside the lecture rooms. The Alumni centre is also happy for us to spread out during breaks rather than being confined to the lobby, and informal use of outdoor areas is allowed.

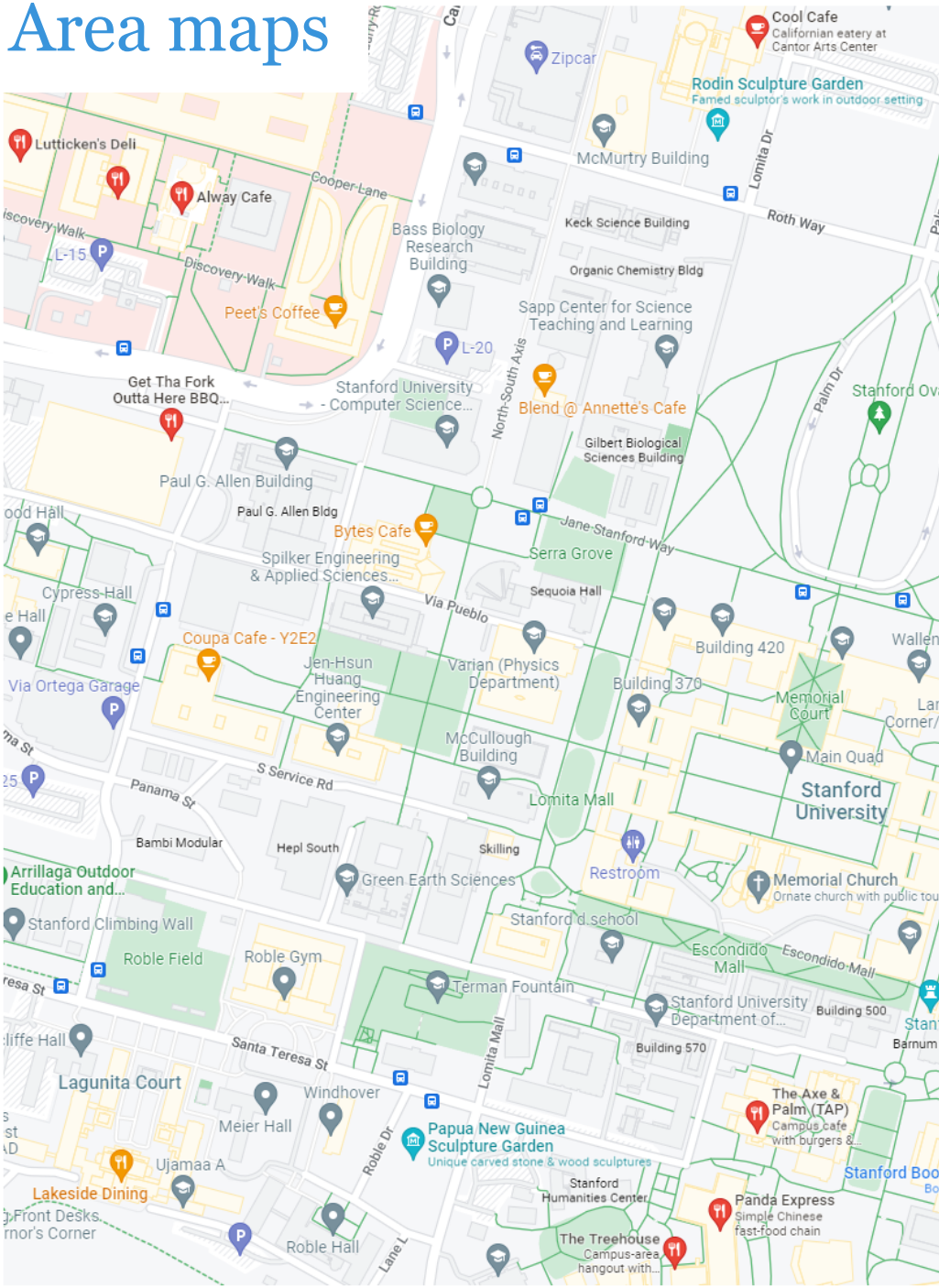
*The lobby will also be used for the poster session on Tuesday September 6th. Posters are to be put up at 5pm.

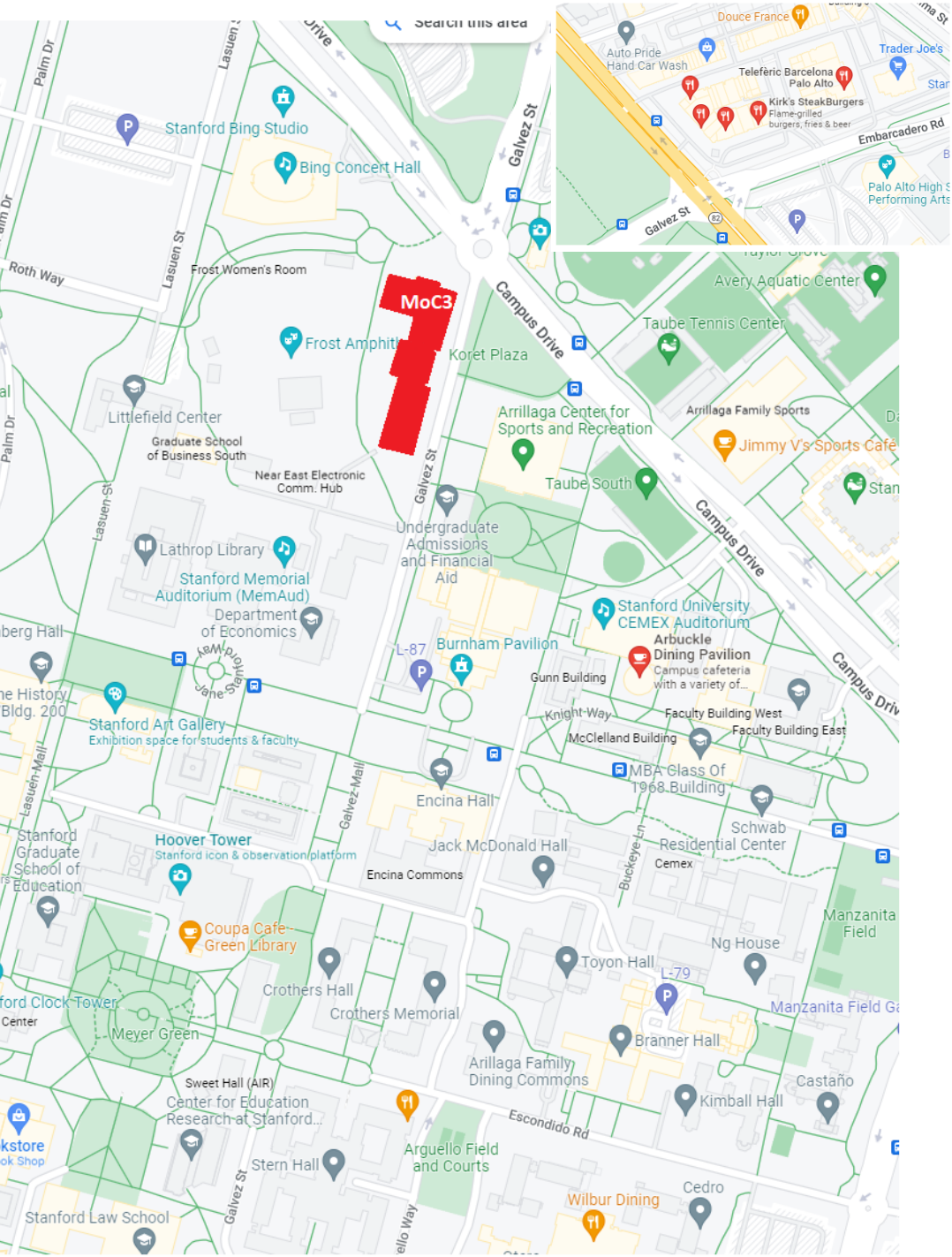
Lunch

There are several Café located across the Stanford campus to explore during the one and a half hour lunch brakes from 12:30 to 2pm. A map showing some of these locations is provided on the following page. Options closest to the Alumni Centre are:

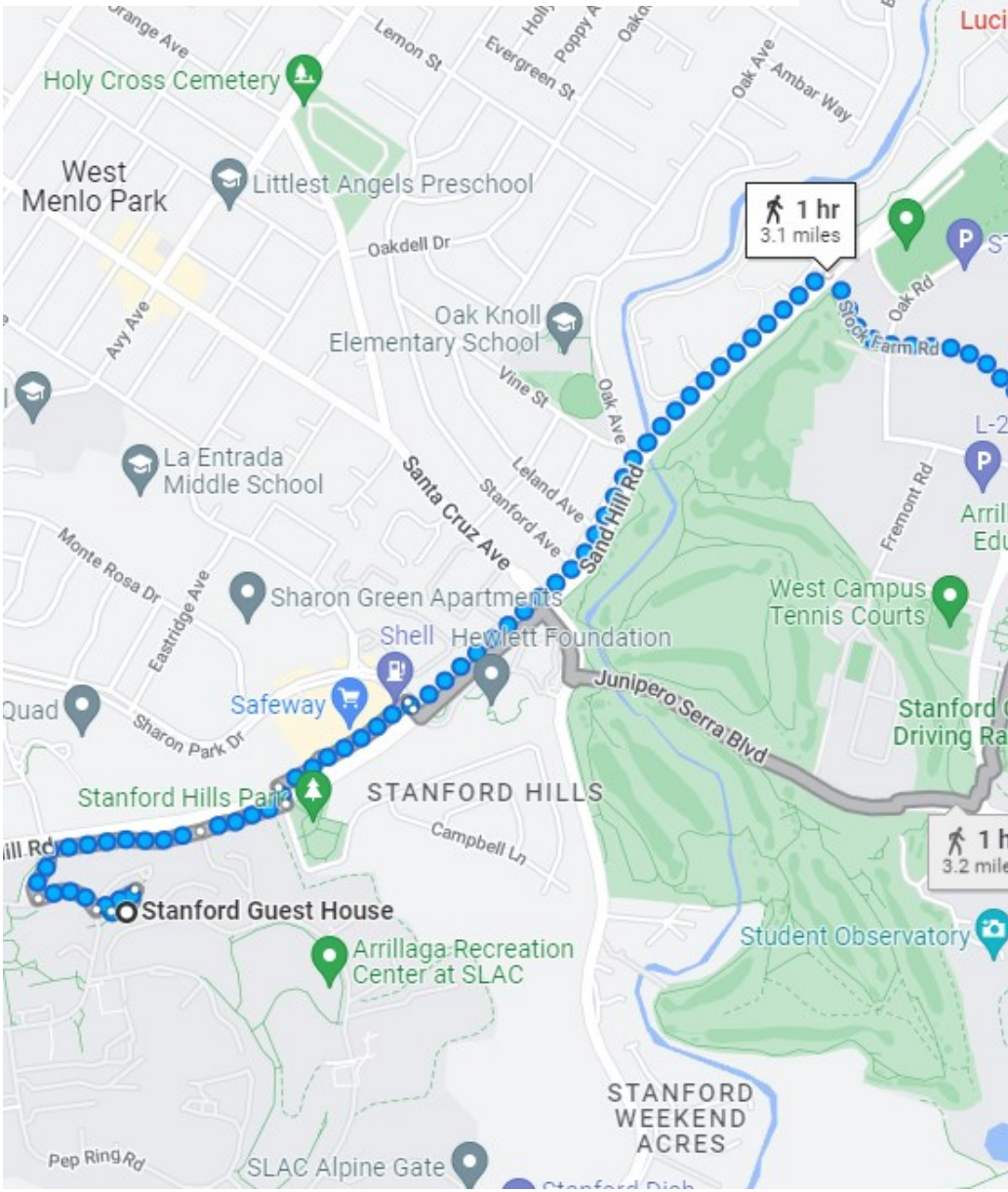
- Arbuckle Dining Pavilion (655 Knight Way, Stanford, CA 94305);
- Jimmy V's Sports Café, (641 Campus Drive, Stanford, CA 94305).

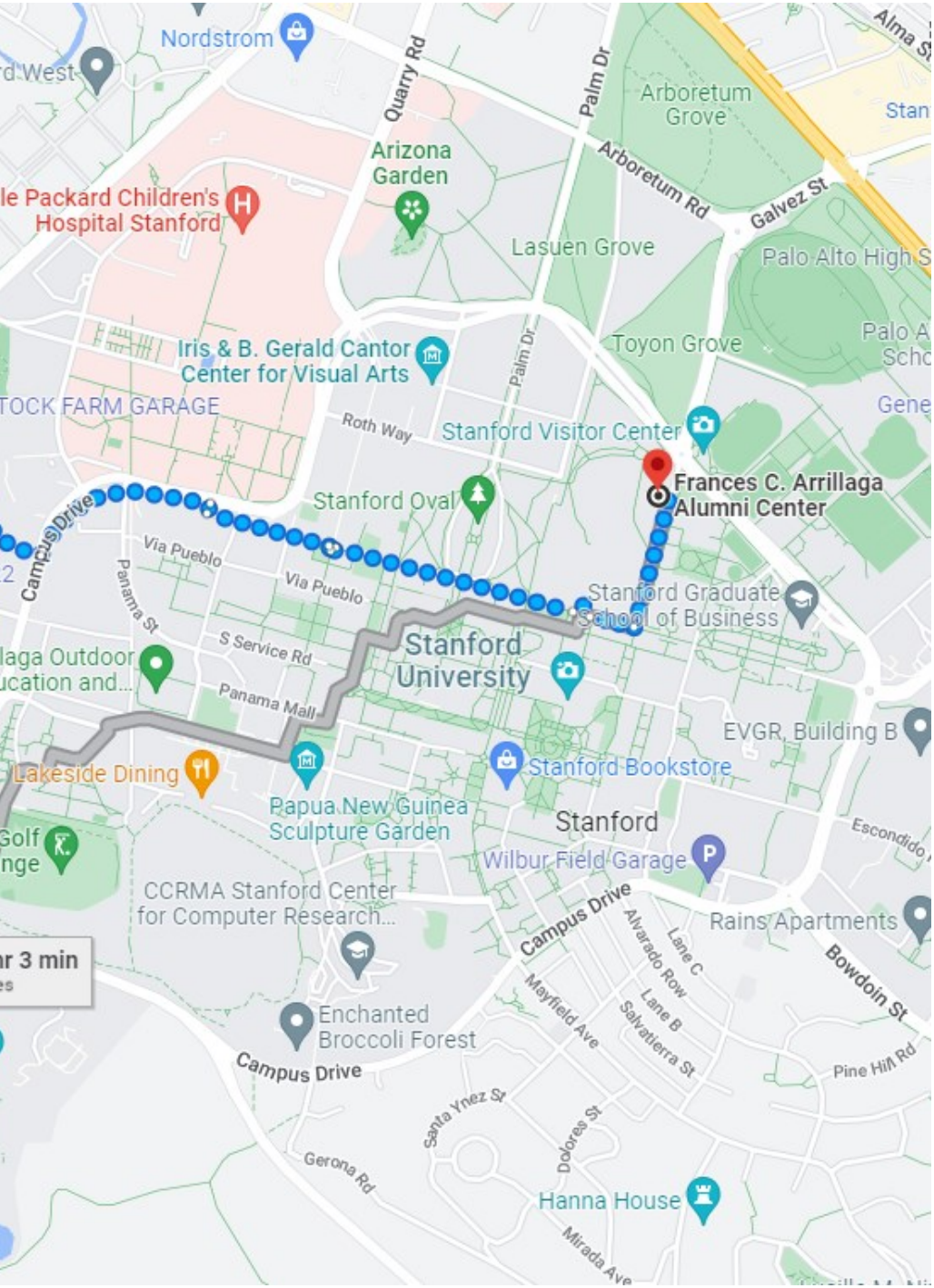
Area maps


Cool Cafe
Californian eatery at Cantor Arts Center
Zipcar
Rodin Sculpture Garden
Famed sculptor's work in outdoor setting
McMurtry Building
Lomita Dr
Roth Way
Lutticken's Deli
Alway Cafe
Cooper-Lane
Discovery-Walk
L-15
Bass Biology Research Building
Keck Science Building
Organic Chemistry Bldg
Peet's Coffee
Sapp Center for Science Teaching and Learning
L-20
North-South Axis
Palm Dr
Stanford Ova
Get Tha Fork Outta Here BBQ...
Stanford University - Computer Science...
Blend @ Annette's Cafe
Gilbert Biological Sciences Building
Paul G. Allen Building
Paul G. Allen Bldg
Bytes Cafe
Jane-Stanford-Way
Serra Grove
Spilker Engineering & Applied Sciences...
Sequoia Hall
Via Pueblo
Cypress Hall
Coupa Cafe - Y2E2
Jen-Hsun Huang Engineering Center
Varian (Physics Department)
Building 420
Building 370
Memorial Court
Main Quad
Stanford University
Via Ortega Garage
McCullough Building
S Service Rd
Panama St
Lomita Mall
Bambi Modular
Hepl South
Skilling
Restroom
Memorial Church
Ornate church with public tou
Arrillaga Outdoor Education and...
Green Earth Sciences
Stanford Climbing Wall
Stanford d.school
Roble Field
Roble Gym
Escondido Mall
Terman Fountain
Stanford University Department of...
Building 500
Building 570
Santa Teresa St
Lagunita Court
Windhover
Meier Hall
Lomita Mall
Roble Dr
Papua New Guinea Sculpture Garden
Unique carved stone & wood sculptures
The Axe & Palm (TAP)
Campus cafe with burgers &...
Ujamaa A
Lakeside Dining
Stanford Humanities Center
Panda Express
Simple Chinese fast-food chain
Roble Hall
The Treehouse
Campus-area hangout with...


Search this area
Douce France
Auto Pride Hand Car Wash
Trader Joe's
Teleférico Barcelona Palo Alto
Kirk's SteakBurgers
Flame-grilled burgers, fries & beer
Embarcadero Rd
Palo Alto High S
Performing Arts
Galvez St
Stanford Bing Studio
Bing Concert Hall
Roth Way
Frost Women's Room
MoC3
Frost Amphitl
Koret Plaza
Campus Drive
Avery Aquatic Center
Taube Tennis Center
Littlefield Center
Graduate School of Business South
Near East Electronic Comm. Hub
Arrillaga Center for Sports and Recreation
Arrillaga Family Sports
Jimmy V's Sports Café
Taube South
Undergraduate Admissions and Financial Aid
Lathrop Library
Stanford Memorial Auditorium (MemAud)
Department of Economics
Stanford University CEMEX Auditorium
Arbuckle Dining Pavilion
Campus cafeteria with a variety of...
L-87
Burnham Pavilion
Gunn Building
Knight Way
Faculty Building West
Faculty Building East
McClelland Building
MBA Class Of 1968 Building
Stanford Art Gallery
Exhibition space for students & faculty
Encina Hall
Schwab Residential Center
Cemex
Hoover Tower
Stanford icon & observation platform
Jack McDonald Hall
Encina Commons
Stanford Graduate School of Education
Coupa Cafe - Green Library
Manzanita Field
Ng House
Toyon Hall
L-79
Crothers Hall
Crothers Memorial
Meyer Green
Manzanita Field Ga
Branner Hall
Arillaga Family Dining Commons
Sweet Hall (AIR)
Center for Education Research at Stanford...
Kimball Hall
Castaño
Escondido Rd
Arguello Field and Courts
Stern Hall
Cedro
Wilbur Dining
Stanford Law School
Lasuen St
Galvez St
Palm Dr
Jane Stanford Way
Lasuen Mall
Galvez Mall
Buckeye Ln

If needing to walk from the Guest House




Nordstrom
Quarry Rd
Palm Dr
Arboretum Grove
Arizona Garden
Arboretum Rd
Galvez St
Lasuen Grove
Palo Alto High S
Iris & B. Gerald Cantor Center for Visual Arts
Toyon Grove
Palm Dr
TOCK FARM GARAGE
Roth Way
Stanford Visitor Center
Frances C. Arrillaga Alumni Center
Stanford Oval
Campus Drive
Via Pueblo
Via Pueblo
Panama St
Stanford Graduate School of Business
S Service Rd
Stanford University
Panama Mall
Lakeside Dining
Papua New Guinea Sculpture Garden
Stanford Bookstore
EVGR, Building B
Stanford
Wilbur Field Garage
CCRMA Stanford Center for Computer Research...
Campus Drive
Rains Apartments
Bowdoin St
Alvarado Row
Lane C
Lane B
Salvatierra St
Mayfield Ave
Enchanted Broccoli Forest
Campus Drive
Pine Hill Rd
Santa Ynez St
Dolores St
Gerona Rd
Hanna House
Mirada Ave
r 3 min

Breakfast and free buses

Stanford Guest House breakfast and transport options. *All the buses listed below are **free** to use, but please do bring your **face masks**.*

Monday September 5th

9:30am* Excursion coach from the Guest House (also see page 8)

Tuesday September 6th (earlier start to allow for registration)

7:15am** Conference bus
From the Guest House to the Arbuckle Dining Pavilion.

7:23am**** Marguerite Shuttle
From the SLAC Arrillaga Science Center stop near the Guest House to Cypress Hall on the west side of campus.

8:00am* Conference bus
From the Guest House direct to the Alumni Centre.

8:03am* Marguerite Shuttle
From the SLAC Arrillaga Science Center stop near the Guest House to Cypress Hall on the west side of campus.

Wednesday 7th to Friday 9th September

7:23am**** Marguerite Shuttle
From the SLAC Arrillaga Science Center stop near the Guest House to Cypress Hall on the west side of campus.

7:45am** Conference bus
From the Guest House to the Arbuckle Dining Pavilion.

8:03am**** Marguerite Shuttle
From the SLAC Arrillaga Science Center stop near the Guest House to Cypress Hall on the west side of campus.

8:30am*** Conference bus
From the Guest House direct to the Alumni Centre.

Breakfast recommendations for those at the Guest House

* Before bus - Verve Coffee, outside the front of the Guest House.

** After bus - Arbuckle Dining Pavilion (open 7:30am), on campus.

*** Before bus - SLAC Café (open 8am), opposite Guest House.

**** Try something else on campus, but check opening times.

Programme schedule

	Monday
9:30 9:45	Guest House Pickup Stanford Pickup
10:30 - 4:45	Excursion
5:15 5:30	Stanford drop-off Guest House drop-off

	Tuesday	
From 8:15	Registration (Lobby)	
8:45 - 9:00	Welcome and opening by AMCS President Lenore Blum (LR)	
9:00 - 10:00	Invited Talk (LR) **1 Kobi Kremnizer**	
10:00 - 10:20	Coffee (Lobby)	
10:20 - 10:45	**2 Ian Durham** (LR)	**4 Moritz Kriegleder** (BMR)
10:45 - 11:10	**3 Prem Sewak Sudhish** (LR)	**5 Jesse Van Oostrum** (BMR)
11:10 - 11:35	**6 Sean Tull** (LR)	
11:35 - 12:30	Discussion Session (LR, BMR, CR)	
12:30 - 2:00	Lunch	
2:00 - 3:00	Invited Talk (LR) **7 Lucia Melloni**	
3:00 - 3:30	**8 Carlotta Langer** (LR)	
3:30 - 4:00	Coffee (Lobby)	
4:00 - 4:25	**9 Alexander Maier** (LR)	**11 Tudor Baetu** (BMR)
4:25 - 4:50	**10 Justin Sampson** (LR)	**12 Fernando Soler-Toscano** (BMR)
4:50 - 5:50	Discussion Session (LR, BMR, CR)	
5:50 - 7:00	Lightning talks, poster session (LR, Lobby)	

Key: **LR**=Lane/Lyons/Lodato Room; **BMR**=Barnes/McDowell Room; **CR**=Cranston Room; **Lobby**=Lobby of the Fisher Conference Centre at the Alumni Centre; **MP**=McColl Plaza

	Wednesday	
9:00 - 10:00	Invited Talk (LR) **13 Paul Skokowski**	
10:00 - 10:20	Coffee (Lobby)	
10:20 - 10:45	**14 Ariel Zeleznikow-Johnston** (LR)	**16 Robert Prentner** (BMR)
10:45 - 11:10	**15 Wanja Wiese** (LR)	**17 Camilo Miguel Signorelli** (BMR)
11:10 - 11:35	**18 Johannes Kleiner** (LR)	
11:35 - 12:30	Discussion Session (LR, BMR, CR)	
12:30 - 2:00	Lunch	
2:00 - 3:00	Keynote Talk (LR) **19 Giulio Tononi**	
3:00 - 3:30	**20 Lenore Blum** (LR)	
3:30 - 4:00	Coffee (Lobby)	
4:00 - 4:25	**21 Manuel Blum** (LR)	**23 Alfredo Vernazzani** (BMR)
4:25 - 4:50	**22 Paul Pu Liang** (LR)	**24 Aramis Valverde** (BMR)
4:50 - 5:50	Discussion Session (LR, BMR, CR)	
6:00 - 7:00	Special Evening Lecture (LR) **25 David Eagleman**	

Key: **LR**=Lane/Lyons/Lodato Room; **BMR**=Barnes/McDowell Room; **CR**=Cranston Room; **Lobby**=Lobby of the Fisher Conference Centre at the Alumni Centre; **MP**=McColl Plaza

	Thursday	
	Invitees can join for the Consciousness and AI morning and can stay for the Showcase afternoon. See page 9.	
9:00 - 10:00	Invited Talk (LR) **26 Ryota Kanai**	
10:00 - 10:20	Coffee (Lobby)	
10:20 - 10:45	**27 Arthur Juliani** (LR)	**30 Andrew Duggins** (BMR)
10:45 - 11:10	**28 Joscha Bach** (LR)	**31 Joanna Szczotka** (BMR)
11:10 - 11:35	**29 Ruairidh Battleday** (LR)	**32 Anna Ciaunica** (BMR)
11:35 - 12:30	Discussion Session (LR, BMR, CR)	
12:30 - 2:00	Lunch	
2:00 - 2:30	**33 Jonathan Mason** (LR)	
2:30 - 3:00	**34 Stuart Hameroff** (LR)	
3:00 - 3:30	Coffee (Lobby) - Guests arrive for coffee	
3:30 - 4:00	**35 Carolyn Dicey Jennings** (LR)	36 MCS intro for Guests only (BMR)
4:00 - 5:00	Invited Showcase Talk (LR), Guests also go to (LR) **37 Pete Grindrod**	
5:00 - 6:00	Drinks reception (MP), Guests chat over drinks	
6:00 - 8:00	Conference Dinner (MP), Guests can join the dinner	

	Friday	
9:00 - 10:00	Invited Talk (LR) **38 Donald Hoffman**	
10:00 - 10:20	Coffee (Lobby)	
10:20 - 10:45	**39 Chetan Prakash** (LR)	**42 Shanna Dobson** (BMR)
10:45 - 11:10	**40 Adam Safron** (LR)	**43 John Barnden** (BMR)
11:10 - 11:35	**41 Chris Rourk** (LR)	**44 Martin Hilbert** (BMR)
11:35 - 12:30	Discussion Session (LR, BMR, CR)	
12:30 - 2:00	Lunch	
2:00 - 3:00	Invited Talk (LR) **45 Katie Warnaby**	
3:00 - 3:30	**46 Raphael Milliere** (LR)	
3:30 - 4:00	Coffee (Lobby)	
4:00 - 5:00	Closing Discussion (LR)	

Key: **LR**=Lane/Lyons/Lodato Room; **BMR**=Barnes/McDowell Room; **CR**=Cranston Room; **Lobby**=Lobby of the Fisher Conference Centre at the Alumni Centre; **MP**=McColl Plaza

Talk titles and abstracts

1 Kobi Kremnitzer (Invited)

OMCAN, Mathematical Institute, University of Oxford, UK

Scientific theories of consciousness, the closure of the (current) physical, and collapse

In this talk I will argue that in order to develop sceintific theories of consciousness we need to ask two questions: What is consciousness, and how does consciousness interact with the physical world. I will look at possible answers to the second question and relate it to considerations about the closure of the (current) physical. If we assume that current theories of physics are complete, there is very little room for consciousness to interact with the physical world. If we do not assume that current physics gives a complete description of the physical world, I will explain how under mild assumptions quantum collapse theories would be involved in modelling consciousness. I will then give some examples of how such theories look like. This talk is based on joint work with Johannes Kleiner.

2 Ian Durham

Department of Physics, Saint Anselm College, USA

Boolean networks in quantum integrated information theory (qIIT)

While neither classical integrated information theory (IIT) nor its quantum extension (qIIT) specify a set ontology, both give bounds on what ontologies are possible. Boolean networks are typically used as a simple example ontology in classical IIT but extending these networks to the quantum case can prove tricky. In particular, some classical Boolean operations are irreversible and implementing them in a quantum network requires the inclusion of ancilla qubits. Evolving these networks in time requires error correction to be performed on the ancilla qubits if the network is to be considered fully autonomous and thus a closed system. Furthermore, the number of qubits required to implement these systems while guaranteeing unitarity, scales as a power law of the number of classical Boolean operations being implemented. Within the axioms of IIT, this raises a variety of issues including precisely where the causal power lies in such systems.

3 Prem Sewak Sudhish

Department of Physics and Computer Science, Dayalbagh Educational Institute, India

Towards an integrated mathematical model of macro and micro scale consciousness

A key goal of consciousness research is to express the link between consciousness at the macro-scale of the physical world with the micro-scale of

the human brain. Here we describe a topological graph theoretic quantum systems modeling (GTQSM) framework that connects the universal macro-level consciousness with the micro-scale consciousness as implementable in the human brain and body. The mathematical framework we describe is inspired by the work presented in recent seminal papers (Satsangi, 2006, Srivastava et al., 2011, 2014). Here we first describe the mathematical framework for the modelling of microtubules in the brain as n-qudit quantum Hopfield network (Srivastava et al., 2016, 2017), while arguing that extending the model as n (dimensionality of the quantum states) tends to infinity, offers an even higher mathematical abstraction in modelling consciousness systems. We also include experimental results that validate the derivative of these neural network models for visual intelligence (Ratan Murty et al., 2018, 2021). Finally, we describe a practical realization of these abstract mathematical ideas as demonstrated via the unique agroecological Dayalbagh way of life. (Presented jointly with Dr. N Apurva Ratan Murty, McGovern Institute of Brain Research, Massachusetts Institute of Technology, USA).

4 Moritz Kriegleder

Faculty of Philosophy and Education, University of Vienna, Austria

The role of information in the Free Energy Principle

The Free Energy Principle is a computational model of self-organisation that aims for a unified explanation of living and conscious systems. While deriving free energy from physicist von Helmholtz, it has become clear that explaining consciousness with free energy involves different assumptions and novel interpretations in contrast to physics. Recently, the authors focus on an informational interpretation of free energy, where minimising free energy corresponds to minimising uncertainty about future states of the environment. But, as I argue in my talk, a general model of consciousness has to do more ontological work. Framing cognition as minimising uncertainty or equivalently maximising mutual information of the agents model and the environment is ignoring recent important insights in cognitive science and philosophy of mind, such as embodied cognition and enactivism. I review the main points of these approaches to explain consciousness and subjective experience and evaluate the possibilities of the free energy principle to incorporate embodied and enacted inference. A comparison with other models of consciousness highlights the difference in the approaches to explaining the phenomenological qualities of the mind. I conclude that the free energy principle leaves open its ontological commitments and that clarifying the philosophical foundations can aid its future development.

5 Jesse van Oostrum

Data Science Foundations, Hamburg University of Technology, Germany

Free energy minimisation for perception as inference

The contents of our consciousness are influenced by the input we receive from our senses. How this input exactly affects our experiences is still a matter of debate. The theory of predictive processing states that there is a model in the

brain that continuously tries to predict the next sensory input, the so called generative model. Our experiences are then determined by a Bayesian inference process on this model, in which the sensory input is 'explained away' by latent causes. An early mathematical formalisation of this idea is the Helmholtz machine. This uses a separate recognition model to perform inference. More recent applications of the free energy principle use instead the message passing (belief propagation) algorithm to perform inference. We will zoom in on the mathematical details of both approaches and discuss similarities and differences. It turns out that both methods find parameters to optimise a free energy functional. However, for the free energy principle, a separate set of parameter values is found for each individual datum, whereas the Helmholtz machine performs a more gradual optimisation over multiple data at once.

6 Sean Tull

Compositional Intelligence Team (Oxford), Quantinuum / Cambridge Quantum, United Kingdom

A categorical formulation of Predictive Processing and Active Inference

Predictive Processing (PP) aims to provide a principled framework for understanding cognition at both the high level (entire organism) and low level (individual neurons), and has been applied in various ways to understand and model consciousness. We present a formulation of PP, and particularly Friston et al's related framework of Active Inference, in terms of the mathematical language of category theory. We make use of the treatments of probability theory in monoidal categories to describe PP graphically in terms of string diagrams. This provides a clarifying presentation of the key concepts of the theory, including generative models, predictions, inference and free energy, while also making the theory amenable to further modification and generalisation. This builds on previous work which gave a categorical account of the Integrated Information Theory (IIT) of consciousness, allowing both theories to be compared.

7 Lucia Melloni (Invited)

Max Planck Institute for Empirical Aesthetics, Germany

In search of the neural correlates of consciousness: challenges and alternative approaches

Research on the neural footprints of consciousness has made many discoveries in the past 30 years, which have led to the advancement of prominent theories attempting to explain how consciousness fits into the physical world. Despite much progress, important challenges remain. In this talk I will review some of those challenges while advancing some solutions based on open science and adversarial collaboration.

8 Carlotta Langer

Data Science Foundations, Hamburg University of Technology, Germany

Learning to predict requires Integrated Information

The Integrated Information Theory provides a quantitative approach to consciousness and can be applied to neural networks. An embodied agent controlled by such a network influences its environment and is being influenced by it. We use the sensorimotor loop to model the interactions among the agent's brain, body and environment. Thereby we can calculate various information theoretic measures that quantify different information flows in the system, one of which corresponds to Integrated Information. Additionally we are able to measure the interaction among the body and the environment, which leads to the concept of Morphological Computation. Previous research reveals an antagonistic relationship between Integrated Information and Morphological Computation. A morphology adapted well to a task can reduce the necessity for Integrated Information significantly. This creates the problem that embodied intelligence is correlated with reduced conscious experience. In this talk we propose a solution to this problem. More precisely, we theorize that a high Integrated Information value is necessary for an agent to predict the next sensory state. We demonstrate the dynamics of the measures in a simple experimental setup in which the agents learn by using the em-algorithm. The results support the hypothesis that integrated information is necessary for learning.

9 Alexander Maier

Department of Psychology, Vanderbilt University, USA

Direct empirical support for the mathematical formalism of Integrated Information Theory of consciousness

Integrated Information Theory (IIT) is unique among neuroscientific theories of consciousness. IIT provides rigorous mathematical formalism built on a small set of axioms with high epistemic certainty. IIT has undergone several iterations since its inception. During its first two iterations, empirical tests of IIT were largely limited to indirect tests of IIT's axiomatic foundations. That is, rather than applying IIT's equations to neural data directly, experimentalists tested IIT via its qualitative predictions. This situation changed with the third iteration of the theory (IIT 3.0). In 2021 Leung et al., showed that direct application of IIT 3.0's mathematical equations to neural data quantitatively distinguished between awake and anesthetized preparations in invertebrate animals. Here we extend this observation to mammals, including humans. Specifically, we show that IIT's formalism successfully distinguishes between varying states of consciousness in various sets of neural data, ranging from single neurons to whole-brain fMRI. We applied IIT 3.0 to both legacy paradigms for the study of neural correlates of consciousness (NCC), as well as resting-state functional MRI with varying state of vigilance. In all cases, IIT 3.0 could not be falsified. Instead, IIT performed according to predictions, resulting in increasingly strong empirical support for its theoretical foundations.

10 Justin Sampson

Computer Science, San Francisco State University, USA

Integrated Information Theory of consciousness in conventional computing

According to integrated information theory, consciousness is associated with the physical cause-effect structure of a system, not its functional behavior. Previous work by Findlay et al. has suggested that a conventional computer running a simulation program does not have the same cause-effect structure as the system being simulated, because the general-purpose logic of the computer cannot be grouped into distinct "black boxes" corresponding to the elements of the simulated system. This talk will extend that work by analyzing how the program that is running on a computer influences its cause-effect structure. First, the oscillation of a computer's clock will be treated as a background condition. Second, a causal model will be described with flip-flops as its micro elements, rather than transistors or gates. Third, a well-formedness constraint on system states will be defined and justified in a principled manner. Finally, a procedure for tracing the causal relationships between bits of a computer's memory will be illustrated using a toy computer architecture, showing how different ways of writing a program may produce different cause-effect structures. This partially confirms the dissociation between intelligence and consciousness from Findlay et al. while offering a way forward for recognizing consciousness arising from some computer programs.

11 Tudor Baetu

Arts et philosophie, Université du Québec à Trois-Rivières, Canada

Informational models of the phenomenon of consciousness and the mechanistic project in neuroscience

I argue that the main contribution of informational models of consciousness, including the popular Integrated Information Theory (IIT), is methodological in nature, amounting to a quantitative recharacterization of the phenomenon of consciousness. This recharacterization offers a more detailed and complete description of the phenomenon; provides the basis for assessment methods of accrued sensitivity, specificity, and content validity; and is expected to guide mechanistic research. However, the issue of the physical interpretation of informational relationships underpinning quantitative models of the phenomenon of consciousness is open to debate. In particular, the panpsychist interpretation proposed by IIT is insufficiently well justified and plagued by internal contradictions.

12 Fernando Soler-Toscano

Universidad de Sevilla, Spain

Information structures and consciousness

This is a joint presentation by José A. Langa, José R. Portillo and Fernando Soler-Toscano. Brain states emerge through continuously evolving dynamics of brain networks. The usual way of modelling these dynamics is by using

stationary systems: there is one structure (attractor) which is responsible of the brain dynamics. We adopt a different approach by characterising the brain activity through a landscape of informational structures (IS) changing in time. The IS is determined by the parameters characterizing the dynamical systems and has cause-effect power in the system's behabiour. In serveral papers we have related IS to IIT postulates. We look at several properties related to how the different brain networks interact not in the empirical data (fMRI signal) but in the information structure underlying it. These properties provide measures strongly related with relevant characteristics of conscious activity, such as metastability, information integration or synchronisation. The distribution of IS measures is studied for healthy controls (HC) and two groups of post-comatose patients with disorders of consciousness (DOC): minimally conscious state (MCS) and unresponsive wakefulness syndrome (UWS). Based on IS measures, machine learners classifiers identify the state of consciousness with an outstanding discrimination (precision of 95.6% por HC/DOC and 86.6% for MCS/UWS).

13 Paul Skokowski (Invited)

Centre for the Explanation of Consciousness, CSLI, Stanford University, USA

Detecting qualia

The hard problem of consciousness really is hard, and what makes the problem so hard is accounting for the contents of experience: qualia. This talk will consider several theories of mind, and briefly discuss their shortcomings when explaining qualia. It will be proposed that these theories have been looking in the wrong place. To give one example, when we peer in the brain, no matter how hard we try and with whatever methods we use, we can't seem to find qualia. Yet when we observe the world, qualia are everywhere: colors, sounds, tastes, smells. Perhaps, then, we need to look outward. In order to overcome the difficulties of previous theories, and make progress in understanding qualia, it will be suggested that the senses should be interpreted as physical detectors. A new theory will be proposed which retains multiple realizability while allowing for a scientifically-based approach towards accounting for qualia in the natural world.

14 Ariel Zeleznikow-Johnston

Turner Institute, School of Psychological Sciences, Monash University, Australia

Aligning qualia structures between people: is qualia inversion possible?

"Is my 'red' your 'green'?" is exemplary of the problem of inverted qualia. If a given quality of an experience can be completely characterised through its potential relationships with other qualities, it may provide a potential path to an answer. This relational idea of qualia is inspired by a mathematical formulation: the Yoneda lemma in category theory. This relational scheme implies a way in which qualia inversion could be ruled out: if two individuals possess the same similarity relationships between their colour experiences, then those individuals experience the same colours. This is especially clear if the underlying

structures are inhomogeneous. To test whether this constraint exists empirically, we collected similarity ratings for a sample of 93 colours across 487 online participants. Instead of providing judgments for all possible pairs, individual participants reported on a subset of the combinations, which we randomly aggregated to generate two independent similarity matrices. As speculated, when sufficient colours are examined to reveal complexity in the similarity matrices we were able to 'align' the two using an unsupervised optimal transport algorithm with near-perfect performance. Our results imply that inverted qualia could only hold for simplistic, low-dimensional qualia structures, which may not find any real-world correspondence.

15 Wanja Wiese

Institute of Philosophy II, Ruhr University Bochum, Germany

How can minimal mathematical models of consciousness promote the science of consciousness?

Minimalist approaches to consciousness differ in scope and purpose, but often share a commitment to the goal of generality. Ideally, a general model of consciousness (MoC) applies to all conscious systems. On the other hand, it is desirable that a MoC be detailed enough to enable specific, empirically testable predictions. These goals pull into different directions. Detailed models of the neural mechanisms underlying human consciousness do not apply to all species. Minimal idealised models are too general to add to the insights afforded by detailed models. Even worse, many minimal models can be satisfied by non-conscious systems. Does this mean minimal mathematical models of consciousness, such as the conscious Turing machine (Blum & Blum, 2021; 2021), non-trivial information closure (Chang et al., 2020), or expected float entropy minimisation (Mason, 2019) miss the mark? I shall argue that minimal mathematical approaches can enable operational definitions of features of consciousness, or provide explanatory abstractions of more detailed models. In particular, the goals of generality and detail need not be pursued independently. Referring to mechanistic details may be necessary to test and justify an explanation of consciousness. But the explanatorily relevant difference-makers are likely to be found at levels targeted by minimal models.

16 Robert Prentner

Munich Center for Mathematical Philosophy, LMU Munich, Germany

Mathematized phenomenology and the scientific study of consciousness

Many consciousness researchers share the idea that a science of consciousness ultimately needs to target the phenomenological properties of experience. However, when looking at most current theories in the scientific study of consciousness, it is unclear what exactly those properties are supposed to be, how they are operationalized within these theories, and whether this could be systematized. The scientific study of consciousness should therefore pay closer attention to the phenomenology of consciousness beyond encoding top-level intuitions or cherry-picking ideas. A sometimes-neglected philosophical discipline, phenomenology, has tried to more

specifically outline the invariant structures that underlie conscious, first-personal experience. What is most urgently needed, we claim, is a formalization of these structures that is precise and amenable to empirical practices in the field, in short: to integrate mathematized phenomenology with the scientific study of consciousness. We will briefly review conceptual, theoretical, and methodological issues and sketch some entry points for mathematical consciousness science. In particular, we focus on the project of transcendental phenomenology, namely to specify the conditions of possibility of having an experience (vis-à-vis a description of these experiences "as such").

17 Camilo Miguel Signorelli

Department of Computer Science, University of Oxford, United Kingdom

Mathematical phenomenology, from subjectivity to objectivity through mathematical invariants

Mathematical phenomenology is part of the growing field of mathematics of consciousness. It has its roots in the work of the German mathematician and philosopher Edmund Husserl and evolved into the program "Naturalizing Phenomenology" during the late nineties. Currently, a few models of consciousness claim a mathematical phenomenology approach, however, most of them fail to acknowledge the deep scientific consequences of the original project. In this talk, I will contextualize what is mathematical phenomenology by quickly reviewing the progress in the mathematics of consciousness. Then, I introduce a mathematical and phenomenological perspective based on the foundations of mathematics, particularly category theory and mathematical invariants. This framework allows us to sketch how objectivity naturally arises from subjectivity, making the former secondary and the latter primary. Finally, this move seems to be free of philosophical contradictions and acknowledges rigorous and methodological requirements to study subjective experience.

18 Johannes Kleiner

Munich Center for Mathematical Philosophy, Ludwig Maximilian University of Munich, Germany

Quality spaces: how to represent consciousness mathematically?

The theory of Quality Spaces aims for a principled and systematic representation of qualitative properties or qualia in terms of a mathematical space. Despite its early precursors (Carnap 1967, Goodman 1977, Clark 1993, Rosenthal 1999) it's methodology is not well-known in Mathematical Consciousness Science. In this talk I will summarize the methodology in mathematical terms, review pros and cons, and identify which improvements are needed in order to achieve a representation of consciousness proper.

19 Giulio Tononi (Invited Keynote)

Institute for Sleep and Consciousness, University of Wisconsin-Madison, USA

IIT 4.0: from phenomenology to physics
IIT is a theory of consciousness that aims at accounting for the properties of experience in physical terms. It identifies the essential properties of experience (axioms), infers the necessary and sufficient properties of its physical substrate (postulates), and expresses them in mathematical terms. In principle, the postulates allow to determine, for any system of elements in a state, whether it has consciousness, how much, and the specific experience it is having. IIT offers a parsimonious explanation for empirical evidence, makes testable predictions, and permits inferences and extrapolations. IIT 4.0 incorporates several developments of the past ten years, including a more precise translation of axioms into postulates and mathematical expressions, the introduction of a unique measure of intrinsic information that is consistent with the axioms, and an explicit assessment of causal relations.

20 Lenore Blum

Center for Conscious AI, Computer Science, Carnegie Mellon University and UC Berkeley, United States

Insights from the Conscious Turing Machine - a machine model for consciousness (1)
The Conscious Turing Machine (CTM) is a simple substrate-independent Theoretical Computer Science (TCS) model of consciousness. Its formulation is inspired by Alan Turing's simple yet powerful model of computation and Bernard Baars' Global Workspace model of consciousness. The CTM is not a model of the brain; it is much too simple for that. It is a machine model for consciousness. It is intended to give insight into phenomena of consciousness that apply in general to any animal or machine whose brain can be described at a high level by the CTM. The CTM provides an understanding of how conscious experiences might be generated; its findings are mostly confirmed, at a high level, by cognitive neuroscience literature. In Part 1, we describe the CTM and indicate how TCS principles of computation and complexity are incorporated into its design. A discussion of insights from the CTM follows in Part 2. This is joint work of Lenore, Manuel and Avrim Blum.

21 Manuel Blum

Center for Conscious AI, Computer Science, Carnegie Mellon University and UC Berkeley, United States

Insights from the Conscious Turing Machine - a machine model for consciousness (2)
After Part 1, Part 2 discusses insights from the Conscious Turing Machine (CTM) for a few puzzling phenomena. For example, ¿Why is it that people in great pain find it difficult if not impossible to sleep? Sleep, after all, helps the body heal itself.* Not being able to sleep when the body desperately needs sleep is surely counter to Darwinian evolution. What is going on? We describe

how the CTM model accounts for this puzzle. We follow with explanations from the CTM for other phenomena associated with consciousness such as the experience (versus the simulation) of pain/pleasure; illusions (pain is assuredly not an illusion); dreams; and free will. This is joint work of Manuel, Lenore and Avrim Blum.

*Elizabeth Shimer Bowers, When Pain Interrupts Your Sleep, webmd (2011). https://www.webmd.com/sleep-disorders/features/pain-and-sleep

22 Paul Pu Liang

Machine Learning Department, Carnegie Mellon University, United States of America

Brainish: Formalizing a multimodal language for intelligence and consciousness

Having a rich multimodal inner language is an important component of human intelligence that enables core cognitive functions such as multimodal prediction, translation, and generation. Building upon the Conscious Turing Machine (CTM), a machine model for consciousness proposed by Blum and Blum (2021), we describe the desiderata of a multimodal language called Brainish, comprising words, images, audio, and sensations combined in representations that the CTM's processors use to communicate with each other. We define the syntax and semantics of Brainish before operationalizing this language through the lens of multimodal artificial intelligence, a vibrant research area studying the computational tools for processing information from heterogeneous signals. Our framework for learning Brainish involves (1) unimodal encoders to represent unimodal data, (2) a coordinated representation space that composes unimodal features to derive holistic multimodal meaning, and (3) decoders to map representations into predictions or raw data (for translation or generation). Through discussing how Brainish is crucial for communication in order to achieve consciousness in the CTM, and by implementing Brainish and evaluating its multimodal intelligence capabilities on several real-world image, text, and audio datasets, we argue that such an inner language will be important for advances in machine models of intelligence and consciousness.

23 Alfredo Vernazzani

Institut für Philosophie II, Ruhr-Universität Bochum, Germany

Stabilizing subjective phenomena via isomorphism

Jean Petitot has offered a rigorous mathematical model of Husserl's account of phenomenal salience — the relation between experienced qualities (e.g. colors) and forms. He has then shown that the same model used to "mathematically translate" conscious perceptual experience can be used to model the neurogeometry of the functional architecture of V1. However, it is not clear what is the epistemic role of such isomorphism. In this talk, I develop a suggestion made by Vernazzani (2020), regarding the role of isomorphism in phenomenal stabilization. In particular, I argue that Dennett's (1991, also Schwitzgebel 2011) concerns about first-person reports can be framed in terms

of lack of robustness for first-person reports, i.e. first-person reports may describe merely artefactual phenomena, rather than characterizing genuine conscious phenomena. This problem is particularly pressing in light of perceptual-completions (e.g. subjective contours, etc). Using Petitot's model I show how achieving a psychoneural isomorphism between mathematical models of neural activity and of first-person descriptions, while it does not provide an explanation of conscious experience, can be used to stabilize subjective phenomena (Feest 2011), i.e. it can be used to validate the robustness of the putative subjectively experienced phenomena.

24 Aramis D. M. Valverde

Cognitive and Information Sciences, University of California, Merced, United States of America

Explaining conscious report: a functional, mechanistic, and quasi-representationalist neural systems framework

The human brain remains the only system which is known to exhibit and report consciousness. Given how little is known about consciousness outside of its instantiating strata, an account of the nature of conscious report ought to be informed by the function and structure of the system that gives rise to it. In this talk I will outline a general neuro-biologically and mathematically informed framework for a system for conscious report. The system is composed of three interconnected sub-functions, a directed hyper-graph like representational space instantiated by directed hyper-graph neural networks and propagations through them, a change detection mechanism, and a self-modifying evaluation mechanism. I demonstrate how the these systems can possibly instantiate a series of functions on representations which together account for the perceived ineffability of consciousness and the separability of representations. Philosophic and experimental implications are also considered.

25 David Eagleman (Invited Special Evening Lecture)

Department of Psychiatry & Behavioral Sciences, Stanford University School of Medicine, USA

Natural varieties of conscious experience

One of the challenges of consciousness research is tackling the variety of forms it can take. I will cover three aspects of my research -- synesthesia, time perception, and sensory substitution -- to map out the opportunities for understanding private subjective experience and its natural variety.

26 Ryota Kanai (Invited)

ARAYA Inc, Japan

Consciousness meets AI for a new paradigm

I will present our current research exploring potential connections between consciousness and intelligence. In this paper we examined how to combine theories of consciousness with modern deep learning techniques to translate high-level concepts from consciousness research into more concrete

computational concepts. Among the theories we considered were Global Workspace Theory (GWT), Information Generation Theory (ITG), and Attention Schema Theory (AST). From this effort, one of the key conclusions is that consciousness has evolved into a platform for general-purpose intelligence. In this talk, I will present a reinterpretation of the GWT as a shared latent space among multimodal specialist modules and outline a roadmap for implementing a Global Latent Workspace (VanRullen & Kanai, 2021) using deep learning techniques, such as an unsupervised translation of representations across latent spaces. With our re-formulation of GWT, we will discuss the functional merits of having a global workspace as well as its implications for neuroscientific research into the brain and the development of brain-to-brain communication technologies.

27 Arthur Juliani

Microsoft Research, USA

On the link between conscious function and general intelligence in humans and machines

In popular media, there is often a connection drawn between the advent of awareness in artificial agents and those same agents simultaneously achieving human or superhuman level intelligence. In this work, we explore the validity and potential application of this seemingly intuitive link between consciousness and intelligence. We do so by examining the cognitive abilities associated with three contemporary theories of conscious function: Global Workspace Theory (GWT), Information Generation Theory (IGT), and Attention Schema Theory (AST). We find that all three theories specifically relate conscious function to some aspect of domain-general intelligence in humans. With this insight, we turn to the field of Artificial Intelligence (AI) and find that, while still far from demonstrating general intelligence, many state-of-the-art deep learning methods have begun to incorporate key aspects of each of the three functional theories. Given this apparent trend, we use the motivating example of mental time travel in humans to propose ways in which insights from each of the three theories may be combined into a unified model. We believe that doing so can enable the development of artificial agents which are not only more generally intelligent but are also consistent with multiple current theories of conscious function.

28 Joscha Bach

Cognitive Artificial Intelligence, Intel Labs, United States

Virtualism as a perspective on the functionality and phenomenology of consciousness

The "hard problem of consciousness" refers to the difficulty of reconciling phenomenal experience with physical mechanisms, and has led a number of theorists to argue that computational simulations may never exhibit the phenomenology of consciousness. Conversely, the virtualist position maintains that consciousness is best characterized as a simulated property, instead of a property of physical systems, and that we can study the conditions under which

systems that are capable of producing simulation models in the service of control will self report awareness of content, mode of attention, reflexive awareness and first person perspective. Functionally, consciousness is understood as a control model of attention in a self organizing information processing agent, tasked with constructing a perceptual scene graph and facilitating attentional learning and compositional reasoning. Each of these concepts will be briefly discussed and operationalized in the context of a cognitive architecture perspective, combining predictive perception, agency, self modeling, homeostatic motivation, and working memory construction via selective attention. Virtualism is not necessarily a new and unique position, but shows significant overlap with eg. Michael Graziano's Attention Schema Theory, Bernard Baars' and Stanislas Dehaene's Global Workspace Theory Thomas Metzinger's Self Model Theory of Subjectivity, and Yoshua Bengio's Consciousness Prior.

29 Ruairidh Battleday

Computer Science, Princeton University, United States

Towards an NP-hard model of consciousness

Is consciousness computable? Several papers have recently proposed a deflationary, normative account of consciousness as an illusion resulting from first modeling one's own attentive process and then inaccurately representing the result. To take the idea of modeling seriously, we must consider the computational implications of such a theory. In particular, we can ask what computational complexity class each of these processes must belong to, and speculate on whether a self-modeling process—let alone a brain—could support such computation. Famous examples have been given that argue that at least some cognition abilities are not computable by a Turing machine. Much more commonly, many transformations in perceptive and cognitive phenomena can be shown to be NP-hard. In this paper, we analyze these various arguments, and put forward the conditions that an intelligent system must fulfil to be conscious, and yet still implementable on a computer. The latter is critical for not only the potential creation of artificial intelligence based on the digital computer as its model of computation, but also for deciding which aspects of the "consciousness problem" will be amenable to scientific modeling and pursuit.

30 Andrew Duggins

Westmead Hospital, Department of Neurology, University of Sydney, Australia

Gnomonic projection from objective flat 3-space to subjective hemi-3-sphere

Visual perception is characterized by a boundary, known as the celestial sphere, approaching which objects appear flattened, just as they are depicted near the horizon line on a perspective picture. Perhaps this reflects the inherent geometry of 'subjective space'. A flat subjective space governed by the rules of graphical perspective foreshortens depth while preserving visual angle, but fails to explain veridical straight line experience. Here I propose a primitive

subjective space of isotropic, homogenous, positive curvature: half of the 3D surface of a 4-ball. Objective flat 3-space is tangent to this hemi-3-sphere at the subject position. The transformation from objective flat 3-space is a gnomonic projection, along lines through the center of the hemi-3-sphere. As in the perspective model, the projection preserves visual angle, and foreshortens objective distance, mapping infinite objects to the 2D equator of the hemi-3-sphere. It maps objective straight lines to geodesics through this uniformly curved subjective space. Hypothetically, this primitive geometry of subjective space may be distorted by attention or experience. Even then, the gnomonic projection would remain an immutable objective-to-subjective transfer function. Geodesics through a distorted subjective space would still be perceived as straight, but would no longer map to objective straight lines.

31 Joanna Szczotka

Center for Sleep and Consciousness, School of Medicine and Public Health, University of Wisconsin-Madison, United States

Hierarchical reinforcement learning and the basal ganglia's unique contributions to consciousness

An interdisciplinary dialogue between computer scientists and neuroscientists resulted in recognition of remarkable matches between behaviours of various neuromodulators and reinforcement-learning parameters (i.e. dopamine-teaching signal, serotonin-discount factor, acetylcholine-learning rate,etc). The core brain structure implementing RL is striatum, typically dismissed in consciousness research as underlying "unconscious habit formation". However, a closer investigation of almost 100 first-person-reports of patients with various striatal lesions reveals that it provides unique contributions to conscious experience. A critical symptom of these patients, often superficially described as a “deficit of action initiation” entails a sensation of "an empty and idle mind", with a striking lack of spontaneous thoughts. Formal HRL distinctions contrasting "exploration" with "exploitation" could meaningfully illuminate some of these symptoms and enrich current frameworks of consciousness. By closely resembling a chaotic oscillator, the globus pallidus in orchestra with subthalamic nucleus are argued to be perfectly situated to contribute to the overall "signal complexity" and parallel an "exploration engine" in HRL. Leaving aside whether NCCs reside in the front or the back of the cortex, I argue that without the striatum, cortex would not be able to explain some of the most ubiquitous but often taken-for-granted aspects of conscious experience.

32 Anna Ciaunica

Co-Embodied Self Lab (CELab), Centre for Philosophy of Science, University of Lisbon, Portugal

The ‘first prior’: from co-embodiment to co-homeostasis in early life

The idea that our conscious perceptions in the here and now are influenced by prior events and experiences has recently received substantial support and attention from the proponents of the Predictive Processing (PP) and Active Inference framework in philosophy and computational neuroscience. In this

paper we look at how perceptual experiences get off the ground from the outset, in utero. One basic yet overlooked aspect of current PP approaches is that human organisms first develop within another human body. Crucially, while not all humans will have the experience of being pregnant or carrying a baby, the experience of being carried and growing within another person's body is universal. Specifically, we focus on the development of minimal selfhood in utero as a process co-embodiment and co-homeostasis, and highlight their close relationship. We highlight some implications on several critical questions fueling current debates on the nature of conscious experiences, minimal self and social cognition. We explore potential computational modeling avenues underlying the key notion of co-embodied agents and its implications for designing artificial selves, minds and bodies.

33 Jonathan Mason

OMCAN, Mathematical Institute, University of Oxford, UK

Model unity and the unity of consciousness

The unity of consciousness, or, more precisely, phenomenal unity, is an important property of consciousness and an important area of research in mathematical consciousness science and the scientific study of consciousness. Due to the numerous aspects and complexity of consciousness, the property tends to engender loose or inadequate characterizations. This talk highlights the concept, mathematical formulation and initial experimental results of model unity. A system has model unity if a single relational model, stretched across the whole system, is optimal. Alternatively, model unity may only be present for subsystems, although, for systems determining a hierarchy of relational models, model unity may occur at a higher level. As a development in the theory of Expected Float Entropy minimisation, such relational models provide an interpretation of system states and the theory may help to provide insights into questions such as why experience of the visual field is unified and why different people do not have a unified consciousness, for example. Results of four investigations will be given as examples. A postulate will also be given, distilling the foundations of EFE minimisation into a clear statement allowing others to consider whether or not the postulate identifies a self-evident fundamental property of consciousness.

34 Stuart Hameroff

Center for Consciousness Studies, Departments of Anesthesiology and Psychology, The University of Arizona, United States

Superradiance in microtubules - recent developments in the 'Orch OR' theory

Penrose 'objective reduction' ('OR', self-collapse of quantum superposition) is a proposed solution to both the quantum 'measurement problem', and the consciousness 'hard problem'. In a typical microenvironment, OR presumably results in merely random, isolated 'proto-conscious' moments. In the Penrose-Hameroff 'Orch OR' theory, superpositions are 'orchestrated', entangled, and process quantum information in microtubules inside brain neurons (Orch OR

occurring at time t = ħ/E where ħ is the Planck-Dirac constant, and E the gravitational self-energy of the superposition). Are such microtubule quantum states plausible? Recent experiments have shown quantum optical terahertz excitations inside tubulin, subunit protein of microtubules, excitations extending through significant microtubule lengths, and persisting for up to seconds, apparently quantum optical 'superradiance'. General anesthetics dampen the distance and duration of microtubule superradiance (Lewton, 2022). Other evidence shows self-similar patterns of microtubule excitations in terahertz, gigahertz, megahertz, kilohertz and hertz frequencies, suggesting microtubule quantum excitations resonate, entangle and interfere in a multi-scale brain hierarchy. Among theories of consciousness, Orch OR has the most 1) explanatory power, 2) experimental evidence, and 3) connection to brain biology. References:

1. Hameroff S, Penrose R (2014) Phys Life Revs 11(1):39-78,
2. Lewton T (2022) A quantum of consciousness New Scientist 254(3383):8

35 Carolyn Dicey Jennings

Cognitive and Information Sciences, University of California, Merced, United States of America

Does consciousness emerge?

The concept of emergence is central to many scientific and mathematical theories of consciousness, including GWT and IIT. Yet, 'emergence' is an evolving term. Its different meanings allow some to claim that emergence is ubiquitous in nature while others see it as unscientific. That is, 'weak' or 'epistemic' emergence is often seen as ubiquitous, whereas 'strong' or 'ontological' emergence is often seen as unscientific. The former can be applied anytime a pattern is irreducible to its components, whereas the latter can be applied only in the case that a new causal power is borne by the emergent entity. In this talk, I will discuss different contemporary uses of the concept of emergence and how they intersect with theories of consciousness. For instance, Hoel, Albantakis, & Tononi (2013) suggest 'quantifying causal emergence as the supersedence of a macro causal model over a micro one'. I argue that this and other contemporary uses actually fall in between the more traditional forms of 'weak' and 'strong' emergence. I then assess the evidence for these new forms of emergence, arguing that they do not provide the promised insight on the problem of consciousness.

36 Conference organisers (This talk is for guests joining on the Thursday)

Oxford's MCS Showcase Afternoon

Introduction to Mathematical Consciousness Science (MCS)

One of the most exciting new scientific fields to emerge in years. Find out what Mathematical Consciousness Science is and how it can revolutionise the scientific study of consciousness.

37 Peter Grindrod (Invited MCS Showcase Talk)

OMCAN, Mathematical Institute, University of Oxford, UK

Cortex-like systems via range-dependent networks of phase-resetting k-dimensional clocks

We introduce a model for human cortex-like systems via range-dependent networks of phase-resetting k-dimensional clocks. The support for such a model rests on the architecture of neural connections and dynamics within the human cortex, and some recent work that has shown that the densely connected neural columns, each containing 10,000 neurons, behave like k-dimensional clocks, with k~10. These clocks (neural columns) send directed signals to one another that result in phase-resetting events on arrival at the receiving clocks. Such systems posses an *inner life* which, almost as an aside, explains aspects of consciousness such as internal sensations. Such preconditioning for immediately following information processing tasks massively reduces the cognitive load. This can be observed by reverse engineering arrays of high dimensional clocks, under various forcings, and seeing the responses are dominated by a discrete number of dynamical modes (both across the cortex and over time). By adopting theses k-dimensional clocks as the basic layer for an information processing system, all embedded within a suitable directed network, we may simulate 1M dynamical clocks and their connections rather than simulate 10B dynamical neurons and their connections. This is the first time that we have taken-up this approach, as opposed to making very large simulations of full neuron-to-neuron networks. In turn this opens up new possibilities for both *fast thinking* reasoning and information processing. We discuss the whole system dynamics and illustrate it with a number of examples and experiments. Finally we set out some key challenges for further research.

This is first time that we have deployed a *range dependent* directed network of many k-dimensional clocks to model cognition within the cortex, rather than very large scale simulations of all neurons, and all of the neuron-to-neuron connections, because of previously published learning. This novel approach greatly simplifies the challenge. It will contain about 1M neural columns (clocks) when scaled-up, with each shocking others with strong *phase resetting* signals. Such a systems still have an inner life (of dynamical modes) and yet they are far more accessible than simulating 10B neurons and their interactions. We show how forcing at a single clock reaches rapidly across the entire system owing to the *small world* properties of the directed range dependent network of the neural columns (clocks).

38 Donald Hoffman (Invited)

Cognitive Sciences, University of California, Irvine, USA

Fusing agents and qualia: a formal solution to the combination problem

The theory of conscious agents (Hoffman & Prakash, 2014; Fields et al., 2017) is a formal theory of subjects and experiences prior to spacetime and physical objects. Spacetime is one of countless forms of interfaces by which agents

interact. Their interactions are Markovian and form new, more complex, structures that satisfy the definition of conscious agent. Thus new agents arise by dynamical interaction. The Markovian kernels describing the dynamics of new agents drop rank in the asymptotic limit of the dynamics. This drop in rank signals the fusion of subjects and qualia. When n conscious agents interact, the set of possible fusions forms an n-1 simplex: the fusion simplex. The dynamical process by which fusion occurs is described by decorated permutations. These permutations index cells of the positive Grassmannian Gr(k,n). A linear transform takes Gr(k,n) to the amplituhedron, giving amplitudes for spacetime scattering processes. Conscious agent interactions are ontologically primary, and scattering processes in spacetime are interface descriptions.

39 Chetan Prakash

Center for Scholarship on Consciousness, Mathematics, Association for Mathematical Consciousness Studies & California State University, San Bernardino, USA

Conscious dynamic polytopes and physical interfaces

Conscious Agent Theory takes consciousness as fundamental, positing the experience of a physical world as a consequence of dynamics within consciousness. As a minimal first step, conscious agents are assumed to have probabilistic structure, rendering the dynamics of a conscious agent network to be Markovian. Don Hoffman's talk gives a path to solving the combination problem, exhibiting fusion of two agents in terms of an asymptotic "fusion" polytope which, along with a distinguished "Birkhoff polytope," both in the the agent dynamics described by the "Markov polytope." Here we delve deeper into the 3- or higher-agent mathematics of this process, with a view towards the emergence of space-time and quantum behavior as on an interface of a conscious agent. We do this by connecting with particle physics research: In "Grassmanian Geometry of Scattering Amplitudes," Arkany-Hamed et. al. describe how scattering amplitudes can be derived from permutations. Permutations being identical to the Birkhoff polytope, this allows us to ask "What is the mathematical relationship between (1) agent dynamics and fusion and (2) particle scattering in spacetime. This would then demonstrate a nontrivial path to solve the mind-body problem starting with mind and deriving body as an interface representation.

40 Adam Safron

Center for Psychedelics and Consciousness Research, Department of Psychiatry & Behavioral Sciences, Johns Hopkins University School of Medicine, United States

On the degrees of freedom worth having: psychedelics as means of understanding and expanding free will

Free will indicates a capacity for conscious intentions to meaningfully cause actions. Free will may further be said to involve a certain open-endedness wherein agents can explore alternative possibilities and pivot based on novel information. Some notions of free will appear to involve self-contradictory

metaphysics involving “uncaused causes,” but one may even find support for this more “libertarian” free will if it is the case that action selection is influenced by forms of causation that solely exist at intermediate levels of organization at which selfhood and agency emerge, or perhaps even in terms of consciously-experienced intentionality being influenced by processes of limited predictability. I will describe how these capacities for volition and flexibility constitute real patterns that have been (and continue to be) selected over the course of evolution and development. I will then explore how these mechanisms may overlap with serotonergic signaling pathways mediating the effects of psychedelic compounds, potentially helping to explain adaptive significances of these biophysical phenomena. Finally, I will consider how this perspective on psychedelics (in terms of altering various degrees of freedom) may help to identify some of the most important sources of variation both across and within individuals.

41 Chris Rourk

Independent researcher, Intellectual Property, Jackson Walker LLP, USA

Mathematical model for conscious action selection

A mathematical model for conscious action selection is an important aspect of mathematical consciousness science, but models that explain why specific actions are selected based on sensory and neural processing are not well developed. The presentation will discuss an hypothesized action selection mechanism that can be used to model conscious actions as a function of specific neural states. The presentation will include a discussion of the hypothesized mechanism, which is associated with certain catecholaminergic neurons (such as the large dopamine neurons of the SNc) that contain ferritin and neuromelanin in structures that were predicted to support energy transfer between those neurons. Evidence of the hypothesized mechanism from testing will also be discussed, including 1) tests on fixed SNc tissue that provide evidence of electron tunneling in that tissue, and 2) tests on ferritin structures similar to ones found in SNc tissue that provide evidence of electron tunneling over distances as great as 80 microns, and an associated switching function. Additional evidence that was predicted by the hypothesis that was subsequently discovered by other independent testing will also be discussed. The hypothesized mechanism will also be applied to several mathematical consciousness models, including the Global Neuronal Workspace and Integrated Information Theory.

42 Shanna Dobson

University of California, Riverside, Mathematics, University of California, Riverside, United States

Linear, branching, and concurrent time: applications to memory and planning

We extend a previously-developed representation of experienced time, reported in part at MOC 2021, to describe branching constructs in both prospective (planning) and retrospective (event memory) time. We then

consider a further extension to concurrent time streams with cross modulation. These latter are intended to capture, at the level of tractable formalism, the experience of multiple “selves” or “self-components” flowing through interacting, but largely-independent temporal histories, both in the (multiply) experienced past and as projected into anticipated futures. Our formal approach is broadly category-theoretic, employing notions from sheaf theory and from the more recent theory of condensed objects developed by P. Scholze and colleagues. We represent the time operator as a functor between small categories of such objects. This work is one component of a larger investigation into the representation of (prospective and retrospective event memory and experienced time by humans, other organisms, and larger, collective systems.

43 John Barnden

FraMEPhys Research Group, Philosophy Dept & School of Computer Science, University of Birmingham, UK

The need for meta-causation in conscious processes

This talk buttresses a recently published, distinctive, physicalist theory of [phenomenal] consciousness, MDyn, that has been developed mathematically and philosophically. MDyn holds that a conscious process is, at each moment, directly, causally sensitive to its own prior, inner causation (the causation tying it together as a process). In short, that prior causation has meta-causal (higher-order causal) influence on the process’s state going forward. Causation is taken as an objectively existing productive dynamism, real at the world’s basic physical level. Meta-causation (meta-dynamism) is also physically real and basic, and is mathematically formulatable in physical law equations. The talk presents a new formal argument buttressing a central argumentative transition in the theory, going from a crucial basic hypothesis about conscious processes to the claim that they rest on the above meta-causation. That hypothesis (argued elsewhere) is that a conscious process is causally sensitive in *some* distinctive way to its prior history as a process. The talk presents a thought-experiment proving (given certain natural assumptions) that that sensitivity must include direct sensitivity to some distinctive aspect of the particular spatiotemporal region the process has traversed. Further arguments suggest that this distinctive aspect is the spatiotemporally-located causation within the region. Hence meta-causation.

44 Martin Hilbert

DE Computational Social Science, Communication, GG Computer Science, DataLab, Professor, University of California, USA

Modeling interactions of consciousness and our digital mind-extensions: can the mind transcend digital manipulations?

The emergence of consciousness is shaped bottom-up by the brain and top-down by environmental interactions. One current driver of the latter are digital interactions, which act as extensions of the mind. We model these relationships mathematically, and test our derived hypotheses empirically. We note that A.I. driven persuasive technologies act as extensions of the human mind, logging

onto sense-perceptions, thoughts, and feelings. Our general intuition is that minds that transcended the self-identification with thoughts and emotions develop a sort of 'digital immunity' to influences and manipulations of artificial intelligence. We define this kind of self-transcendence in line with Maslow's accepted definition from psychology. The underlying generative mechanism is a capacity for the de-conditioning of mental activity and a self-identification with higher levels of more embracing stages of consciousness. In the case of self-transcendence, it is a de-conditioning from thoughts and emotions, and in the case of digital immunity it is a de-conditioning from (often tailor-made) digital stimuli. This places emphasis on better understanding states of consciousness that transcend thoughts and emotions to a higher level perspective on ones own mental activity (and its digital extensions).

45 Katie Warnaby (Invited)

Wellcome Centre for Integrative Neuroimaging, Nuffield Division of Anaesthetics, University of Oxford, UK

The role of slow waves in anaesthesia-induced loss of consciousness
My work focuses on the exploration of slow waves under anaesthesia using multi-modal human brain imaging. I will present evidence that the saturation of the 1Hz slow wave signal with increasing dose may provide a common cross-agent pathway for anaesthesia-induced loss of consciousness. I will present behavioural and brain imaging data to support the hypothesis that slow wave activity saturation (SWAS) reflects perception loss and isolation of an individual from the external world.

46 Raphaël Millière

Center for Science and Society, Columbia University, United States

A dynamical systems perspective on the multidimensional account of consciousness
In recent years, a debate has emerged regarding the adequate characterization and taxonomy of global states of consciousness, by contrast with specific conscious contents. Examples of global states of consciousness include the ordinary wakeful state, post-comatose disorders of consciousness, and the dreaming state associated with rapid eye movement sleep. The traditional view in clinical neuropsychology is that global states of consciousness can be ranked on a scale corresponding to levels of consciousness, from the "least conscious" to the "most conscious" state. This view has recently been criticized on the grounds that global states of consciousness differ from each other in more than one respect, and thus cannot be easily ranked from least to most conscious. This multidimensional account of global states of consciousness raises a number of oustanding questions about the individuation of dimensions and global states. Here, I propose to address these issues within a formal framework. In particular, I will draw from dynamical systems theory to explore the idea that global states can be adequately modelled as attractors in a multidimensional space.

(47) Oleg Soloviov (Included in sympathy**)

Neuroscience Society of Ukraine, department of psychology, pedagogy and philosophy, Kremenchuk national university of Ukraine, Ukraine

Biological expedience hierarchical relations between neuronal networks of different brain structures explains how and why the mental orchestrates the physical during information processing

Assumption about the mechanism of information activity of the brain can be the assertion that there are hierarchical (control-controlled) relationships in the neural networks of the brain that ensure the integration of information (Tononi G.) during functioning of bottom-up and top-down information flows in it. This allows the body to carry out 'informational-well-enriched-motor-acts' for changing surrounding world in a wished condition. In other words, muscle acts are controlled (orchestrated) by information accumulated and integrated in the brain. However, in this hypothetically correct statement, the critical weakness is that it is, by default, based on the notion that physically active neural networks as physical entities, not entirely clear way, function biologically (or socially) expediently. We eliminate this contradiction by insisting that control-subordinate and, at the same time, biologically/socially expedient functional relationships between neural networks arise in the brain precisely through the functioning of mental phenomena (mind, consciousness) in it. And it is precisely this, “against” physical causality, that determines the functional and causal structure of the mutual influence of neural networks that implement certain mental phenomena (first of all, the ability to subjectively assess the biological value of an external stimulus and the expediency of a particular information operation).

****About abstract (47)**

Due to the war in Ukraine, Oleg Soloviov had to turn down the organising committee's offer of a talk slot. In sympathy, the committee decided to include Oleg’s abstract anyway and hope he will be able to present his talk at a future MoC conference in better times.

Poster & lightning talk titles and abstracts

Amol Kelkar

i3AI.org, USA

Homeostasis theory of cognition and consciousness

Homeostasis, using a suitable definition, is the driving force behind all actions in simple organisms. Nervous systems evolved as homeostatic controllers and early nervous systems were entirely enslaved to fulfilling physiological homeostatic drives. We argue that evolution reused the blueprint of neural circuits originally built as homeostatic controllers to then implement higher cognitive functions. Instead of controlling physiological homeostatic variables, these circuits operate over transient, dynamically configured "cognitive" homeostatic variables (cognitive hvars). We hypothesize that as nervous systems evolve, the ability to setup and follow arbitrary cognitive homeostatic variables would lead to a net decrease in evolutionary fitness due to errant behavior, which can be recovered only if the configuration of cognitive hvars is inescapably grounded on the physiological hvars that represent bodily integrity. This body-to-brain control is implemented as the phenomenology of the “self” process, which is hardwired to experience various physiological hvars as corresponding qualia. Cognitive hvars produce a complex composite of the base experiences, resulting in the rich inner life that conscious organisms experience. A mathematical framework is being developed for this proposal.

David Bickham

Independent, United States

The theory of consciousness

I think of consciousness as I think everyone commonly does. This is a macro, or wholistic definition and theory. I will define it, say what it is for, explain how it works, and explain how it developed over the course of biological history. I have a model that explains subjective experience. I will also define language. I will also show how consciousness forms the basis for society and culture.

Kenneth Shinozuka

Centre for Eudaimonia and Human Flourishing, Psychiatry, University of Oxford, United Kingdom

Applying non-equilibrium thermodynamics to feedback processes in the global workspace

It has been postulated that psychedelics and altered states of consciousness increase entropy production in the brain (Carhart-Harris et al., 2014).

Additionally, novel methods have recently been developed to quantify entropy production at the whole-brain level by measuring irreversibility (Lynn et al., 2021; Deco et al., 2022). However, the underlying mechanisms of entropy production remain unclear. In this talk, I will apply a mathematical framework by Kolchinsky & Wolpert (2021) to demonstrate that feedback processes account for increases in entropy production in a simple, two-layer model of a neural circuit that exhibits bottom-up and top-down modulation of activity. In particular, Kolchinsky & Wolpert use information geometry to show that, in a system whose state is driven from one probability distribution to another by a constrained protocol, the decrease in the KL divergence between the desired and the constrained distributions supplies a lower bound on entropy production. I will argue that Kolchinsky & Wolpert's framework fits models of neural circuits so long as their feedback processes are constrained to process information synergistically (Williams & Beer, 2010). Crucially, synergistic information processing is thought to underlie the integration and broadcasting of neuronal activity in the global workspace (Luppi et al., 2021).

Marco Fabus

Wellcome Centre for Integrative Neuroimaging, Nuffield Department of Clinical Neurosciences, University of Oxford, United Kingdom

Brain state dynamics and neural inertia during anaesthetic loss of consciousness

Anaesthetics are a unique tool in consciousness science as they facilitate reversible loss of phenomenology. Brain imaging during anaesthesia has provided key empirical insights into mechanisms that disrupt consciousness including loss of signal complexity and changes to brain connectivity. However, our knowledge of the brain state trajectory when losing consciousness is still limited. Hidden Markov Modelling (HMM) has emerged as a promising way to identify dynamic, subject-specific brain states in a data-driven way. In this study, we applied the Time-Delay-Embedded HMM to 32-channel electroencephalogram data collected from 16 healthy volunteers (8 female, 28.6±7 years) undergoing an ultra-slow 2-hour anaesthetic cycle up to 4μg/ml propofol effect-site concentration and back. N=10 states were estimated and split-half validated. State-specific spectral information was extracted using multi -tapering. State switching rates, fractional occupancies, and novel temporal asymmetry measures were computed as functions of anaesthetic dose. Several states showed significant association with propofol dose including wakefulness, loss-of-responsiveness, and deep-anaesthesia-specific states. As consciousness was lost, the brain showed more inertia and less state switching, suggesting an altered state energy landscape. This work provides initial evidence that HMM can identify time-resolved, dose-dependent, consciousness-relevant states in anaesthetic brain activity.

Mildreth Hernandez Cruz

Centre for Sociological Research, Faculty of Political and Social Sciences, National Autonomous University of Mexico, Mexico

Network analysis about “4E cognition” models

The main objective of the talk is to represent, through a “network analysis”, created through the ONodo platform, the interdisciplinary interactions (of authors and disciplines) that intersect between the models that make up "4E cognition", that is, embodied , embedded, extended and enactive cognition. The representation of this network will allow us to observe epistemological pluralism in Cognitive Sciences, as well as the interactions that occur between scientists from different disciplines. It's important to mention that “network analysis” is a methodological tool that can represent elements that are not easily observed, therefore having a network has great advantages, especially at a pedagogical level.

Nir Lahav Lahav

Physics, Bar Ilan university, US

Can physics solve the hard problem of consciousness? The new solution of the relativistic theory of consciousness

There is an explanatory gap between our scientific knowledge of functional consciousness and its subjective, phenomenal aspects, referred to as the “hard problem” of consciousness. Naturalistic dualists argue that consciousness composed of a private element. Illusionists, on the other hand, argue that it’s a cognitive illusion. We contend that both the positions are flawed because they assume consciousness to be an absolute property that doesn’t depend on the observer. We developed a new physical approach of a relativistic theory of consciousness in which a system either has or doesn’t have phenomenal consciousness with respect to some observer. Phenomenal consciousness is neither private nor delusional, just relativistic. In the frame of reference of the cognitive system, it will be observable (first-person perspective) and in the other cognitive frame of reference it will not (third-person perspective). These two cognitive frames of reference are both correct, just as in the case of an observer that claims to be at rest while another will claim that the observer has constant velocity. Neither observers frame can be privileged, as they both describe the same underlying reality. Based on relativistic phenomena in physics we developed a mathematical formalization for consciousness which dissolves the hard problem.

Shervin Parsi

Physics, City University of New York, United States

Measuring learned information in neural networks

Defining and measuring learned information in neural networks is the key, and the main challenge, to build an information-theoretic framework to study machine learning problems. We leverage the connection between information theory and thermodynamics to measure the learned information and trace

dynamics of learning in shallow and deep neural networks. The outcome is a well-defined information-theoretic measurement of learned information in deterministic neural networks. Finally, we apply our “thermo-info” measuring tool to study the connection between supervised and unsupervised learning - particularly answering how adding an unsupervised learning component to supervised learning models improves generalization error and investigating an inverse possibility.

Bunker Point, Half Moon Bay, CA, USA

Discussion sessions

Next to talks by invited speakers and participants, this conference will feature discussion sessions in parallel groups. The goal is to create an open and friendly atmosphere in which thoughts and ideas can be exchanged.

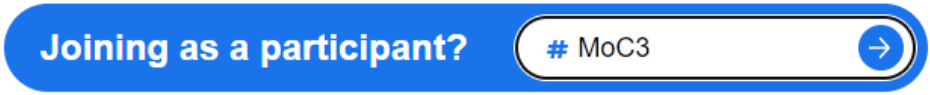
Each discussion session is devoted to one topic, either a specific question/idea related to models of consciousness, or a general question concerning progress and visions of the field as a whole. In addition to various topics which have been proposed in advance by the organizers and the advisory board, new topics can be added during the conference in response to talks or based on general interest.

In order to let those questions emerge that receive the most interest by all participants, a web interface will be used, which allows attendees to indicate their interest in a question, as well as to propose new questions of their own. In order to access this web interface, simply access the following website with any internet device (laptop, cell phone, tablet)

www.slido.com

and enter the event code

#MoC3



for “Models of Consciousness3”.

How to use the web interface:

- In order to indicate that you find a question interesting, click the small “thumbs up” on the right hand side of a symbol.
- In order to add a new discussion topic, simply enter the question into the field at the top. (Please word questions carefully. If questions are not worded well, they might be blocked by moderators.)

The web interface is accessible also in advance of the conference.

Discussions are an integral component of science and we hope that the sessions held during this conference are enjoyable and fruitful. Ultimately, this requires an atmosphere of trust and tolerance supported by all attendees of a session, much like described in the following two quotes by Isaac Asimov and a collaborator of Werner Heisenberg.

"First and foremost, there must be ease, relaxation, and a general sense of permissiveness. The world in general disapproves of creativity, and to be creative in public is particularly bad. Even to speculate in public is rather worrisome. The individuals must, therefore, have the feeling that the others won't object. (...) It seems necessary to me, then, that all people at a session be willing to sound foolish and listen to others sound foolish."
Isaac Asimov, *How do people get new ideas*, 1959

At the center of a discussion with Werner Heisenberg was "the shared problem and the desire to grasp and clarify it. One carefully approached it, passed it to the other, like in a friendly table tennis game, where both made sure that the ball remained in play. All the attention was focused on truly understanding the other and to avoid letting him stumble sophistically over his poor and inadequate expression. One could stutter, one could speak vaguely, even incomprehensibly, and he would guess what one actually wanted to say, would repeat it in his own different words, so that one could often exclaim with pleasure: 'Yes, exactly that...!'. During such an (...) intense exchange of thoughts, the ideas and concepts sharpened, so that their contours became recognizable more clearly."
A former collaborator of W. Heisenberg

Preconference virtual boot camp

MoC3 at Stanford is preceded by a virtual online boot camp the week before on Tuesday 30th August at which the following tutorials are available. Details by email and online; https://amcs-community.org/preconference-virtual-boot-camp.

- **Wanja Wiese** — Philosophy of consciousness
- **Sean Tull** — Category Theory for consciousness science
- **Ian Durham** — Practices and methods for progress in formal scientific research
- **Larissa Albantakis & William Marshall** — IIT 4.0 primer

NOTES

Association for Mathematical Consciousness Science

Fisher Conference Center
Frances C. Arrillaga Alumni Center
326 Galvez Street Stanford
CA 94305-6105
USA