SCiNDU: Systems & Computational Neuroscience Down Under

Tuesday 15th-Thursday 17th December, 2015

Queensland Brain Institute, The University of Queensland, Brisbane, Australia

Program Book

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Australian Research Council
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Integrative Brain Function

Conference Program

Tuesday December 15th

10am–1pm: Tutorials

1pm–2pm Lunch for tutorial attendees

2.30pm–4.00pm: Cortical Processing in Mouse — Chair: Geoff Goodhill

2.30pm	Mark Bear: Higher brain functions served by lowly mouse primary visual cortex.
3.15pm	Ehsan Arabzadeh: Contribution of cortical layers 2/3 to sensory processing in mouse barrel cortex.
3.45pm	Joseph Lizier: Increase in information processing capacity with approach to criticality in developing neural networks.

4.00pm–4.30pm Afternoon tea

4.30pm–5.30pm Modelling Approaches — Chair: Peter Stratton

4.30pm	Michael Breakspear: Nonlinear, hierarchical dynamics in prefrontal cortex modulate the precision of perceptual beliefs.
5.00pm	Mark McDonnell: Can deep-learning algorithms be instantiated in realistic cortical microcircuit models?
5.15pm	Patrick Kasi: The decoding of slowing adapting afferents: a Bayesian approach.

5.30pm–7.00pm: Welcome Reception

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Wednesday December 16th

9.00am–10.30am: Decisions and Disorders — Chair: James Roberts

9.00am	Peter Dayan: Heuristics of control: habitization, fragmentation, memorization and pruning.
9.45am	Peter Robinson: Physiology-based quantitative modelling and analysis of brain activity and structure underlying attention, prediction, and decision.
10.15am	Amir Dezfouli: Learning state-space representation and hierarchical decision-making in rats.

10.30am–11.00am Morning tea

11.00am–12.30pm: (mostly) Human Cognition — Chair: Oliver Baumann

11.00am	Marta Garrido: Predictive and efficient coding in sensory learning.
11.30am	Jason Mattingley: Neural correlates of selective visual attention for interactive approach and avoidance.
12.00pm	Saurabh Sonkusare: Contribution of posterior middle temporal gyrus in semantic control.
12.15pm	Jenny Rodger: Low-intensity repetitive transcranial magnetic stimulation modulates visual evoked responses depending on activity during stimulation.

12.30pm–1.30pm Lunch

1.30pm–3.00pm: Adaptive Behaviour — Chair: Helen Gooch

1.30pm	Zach Mainen: Serotonin and the regulation of adaptive behaviour.
2.15pm	Pankaj Sah: Hippocampal prefrontal circuits that mediate fear learning and extinction.
2.45pm	J Bertran-Gonzalez: Age-related corticostriatal decline underlies temporal constraints in action execution.

3.00pm–3.30pm Afternoon tea

3.30pm–5.00pm Dendritic Processing — Chair: Florence Cotel

3.30pm	Greg Stuart: SK channels and spike-timing dependent plasticity.
4.00pm	Stephen Williams: Active dendritic integration underlies circuit-based computations in the neocortex and retina.
4.30pm	Lucy Palmer: Local dendritic modulation by multi-sensory input.
4.45pm	Rollin Omari: The application of recommendation architecture in managing interference between prior and later learning.

5.00pm–7.00pm: Poster Session

7.00pm–9.30pm: Conference Dinner

Thursday December 17th

9.00am–10.45am: Sleep and Brain Wiring — Chair: Leonie Kirszenblat

9.00am	Yang Dan: Neural circuits for sleep control.
9.45am	Marcello Rosa: Towards a cellular-resolution connectome of the primate brain.
10.15am	Linda Richards: Wiring the brain for function.

10.45am–11.15am Morning tea

11.15am–12.45pm: Insects and Navigation — Chair: Martyna Grabowska

11.15am	Mandyam Srinivasan: Vision and navigation in bees and birds and applications to flying machines.
11.45am	Allen Cheung: Probabilistic learning by rodent grid cells.
12.15pm	Bernard Evans: Salience invariance with divisive normalisation in higher-order insect neurons.
12.30pm	Matthew Van De Poll: Understanding insect habituation and recalibration: learning in a dynamic virtual reality environment.

12.45pm–1.45pm Lunch

1.45pm–3.30pm: Visual Coding — Chair: Lilach Avitan

1.45pm	Li Zhaoping: Looking before seeing: exogenous attentional guidance by the primary visual cortex and its interaction with higher level visual functions.
2.30pm	Hamish Meffin: Contrast dependent phase sensitivity of complex cells in primary visual cortex.
2.45pm	Nicholas Price: Rapid adaptation shapes population activity in middle temporal area consistent with perceptual biases.
3.00pm	Geoff Goodhill: Coding and plasticity in visual maps.

3.30pm: Conference Concludes

Poster Listing

1 Faster responses under low-contrast stimulation in rat V1
Masoud Ghodrati, Dasuni Sathsara Alwis, Nicholas Seow Chiang Price

2 The neuronal and perceptual effects of visual masking
KL Richards, DS Alwis, M Ghodrati, E Arabzadeh, NSC Price

3 Rapid adaptation shapes population activity in middle temporal area consistent with perceptual biases
Elizabeth Zavitz, Hsin-Hao Yu, Marcello GP Rosa, Elise G Rowe, Nicholas SC Price

4 Audiovisual integration in areas MT & MST of marmoset monkeys
Chaplin TA, Allitt BJ, Hagan MA, Price NS, Rosa MGP, Rajan R, Lui LL

5 Response properties of MT neurons to random dot motion stimuli after V1 lesion
Hagan MA, Chaplin TA, Huxlin KR, Rosa MGP, Lui LL

6 Feature selectivity of neurons in the dorsomedial (DM) area of the marmoset visual cortex
Declan Rowley, Saman Haghgooie, Elizabeth Zavitz, Nicholas Price, Marcello Rosa, Hsin-Hao Yu

7 The dorsal visual system predicts future and remembers past eye position
Adam P Morris, Frank Bremmer, Bart Krekelberg

8 Retinal ganglion cells: mechanisms underlying depolarization block
T Kameneva, MI Maturana, AE Hadjinicolaou, SL Cloherty, MR Ibbotson, DB Grayden, AN Burkitt, H Meffin

9 Contrast dependent phase sensitivity of complex cells in primary visual cortex
Meffin H, Hietanen MA, Cloherty SL, Ibbotson MR

10 Irregularly timed biphasic pulses increase efficacy of retinal ganglion cell responses
A Soto-Breceda, MR Ibbotson, H Meffin, T Kameneva

11 Frequency dependence of local field potential responses to electrical stimulation of the retina
Yan T Wong, Kerry Halupka, Tatiana Kameneva, Shaun L Cloherty, David B Grayden, Anthony N Burkitt, Hamish Meffin, Mohit Shivdasani

12 An analytical model of simple cell receptive fields: the two-dimensional Gabor function adapted to natural image statistics
Peter N Loxley

13 Radial orientation selectivity in Linsker-type learning network
Catherine E Davey, David B Grayden, Anthony N Burkitt

14 A new in vitro closed loop neural interface with optical stimulation
F Kemal Bayat, H Özcan Gülçür, Albert Güvenis, Gürkan Öztürk, Bora Garipcan

15 A comparison of the computational methods of burst analysis in neuronal spike trains and their application to recordings of human stem cell-derived neuronal networks
Ellese Cotterill, Paul Charlesworth, Ole Paulsen, Stephen J Eglen

16 Retinal population codes are influenced by field shaping under suprachoroidal stimulation
Calvin D Eiber, John W Morley, Nigel H Lovell, Gregg J Suaning

17 The decoding of slowing adapting afferents: a Bayesian approach
Patrick Kasi, James Wright, Heba Khamis, Ingvars Birznieks, André van Schaik

TALK **TUESDAY 3.15PM**

Contribution of cortical layers 2/3 to sensory processing in mouse barrel cortex

Ehsan Arabzadeh

A challenge of neuroscience is to understand the key computations that underlie information processing in neural circuits. A well-studied system for neural computation is the mammalian neocortex, which exhibits a fine columnar and laminar organisation. The rodent vibrissal-barrel cortex is a good model for cortical processing due to its functional efficiency and well-established synaptic connectivity. Here, we focus on Layer 2 and 3 (L2/3), as a hub in the cortical communication: L2/3 plays a key role in intra-laminar interactions between granular (L4) and infra-granular (L5) layers, and acts as a gateway to other cortical areas. Despite its strategic position in the cortical microcircuit, L2/3 neurons comprise the least spontaneously active neurons and exhibit sparse activation in response to sensory stimulation. In this talk, I present data that quantifies the response characteristics of L2/3 neurons in mouse barrel cortex. By combining whole-cell recording and two-photon calcium imaging, we demonstrate how a sharp rising high-velocity stimulation of vibrissae can reliably drive activity in a majority of L2/3 neurons. We then ask how this "dense" activation of L2/3 neurons affects activity in the cortical network and in turn influences the transformation of sensory information. To address this question, channelrhodopsin-2 is selectively expressed in the excitatory neurons of L2/3 using in utero electroporation. This allows us to quantify how optogenetic activation of L2/3 neurons produces a diverse effect on cells in other cortical layers and results in a normalisation of activity across cortical population.

POSTER NUMBER **57**

Potential, Predicted and Prescient: How to encode representations of time in neural network models

Joshua Arnold, TingTing Amy Gibson, Janet Wiles

The University of Queensland

Event--based neuromorphic sensors provide opportunities and challenges for processing event-based data with a focus on temporal information. Such biologically inspired sensors are low power, with computationally efficient sparse data formats. Many current vision-processing techniques have an implicit assumption that time is discretised into frames that are spatially dense samples containing large amounts of redundant information. This work focuses on new ways to conceptualize and process event-based data from the Dynamic Vision Sensor (DVS). To facilitate research in this area a new event-based dataset has been created featuring very simple motion of dots. A new approach to vision processing which clusters events inspired by the concept of light-cones in Minkowski space-time has been developed and demonstrated on videos from a DVS mounted on moving and stationary robots. Further, different methods of pre-processing event-based data with a focus on minimising the loss of temporal information are analysed for suitability in time-stepped neural network models.

POSTER NUMBER **37**

How do spontaneous neural assemblies change over development?

Lilach Avitan[1], Nicholas J Hughes[2], Zac Pujic[1], Biao Sun[1], Ethan K Scott[3], Geoffrey J Goodhill[1,2]

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[3]School of Biomedical Sciences, The University of Queensland, Brisbane QLD 4072, Australia

Even in the absence of sensory stimulation the brain is remarkably active. This ongoing spontaneous activity generally takes the form of structured cell assemblies, which may represent network states tuned to behaviourally relevant features. However, little is known about how the spatial and temporal dynamics of these assemblies evolve during development. The zebrafish optic tectum provides an ideal system for examining these questions. Here, we used two-photon calcium imaging of intact zebrafish larvae from ages 4-9 days post fertilization to reveal the changing structure of spontaneous activity across development in the tectum. This helps elucidate the principles of self-organisation the brain uses while forming functional neural circuits.

POSTER NUMBER **14**

A new *in vitro* closed loop neural interface with optical stimulation

F Kemal Bayat, H Özcan Gülçür, Albert Güveniş, Gürkan Öztürk, Bora Garipcan

[1] Marmara University, Istanbul, Turkiye
[2] Boğaziçi University, Istanbul, Turkiye
[3] Medipol University, Istanbul, Turkiye

Closed loop neural interfaces, where neuronal signals are detected and used for determination of feedback stimulation in real time, provide platforms for network level investigations of dissociated cultures of neurons. In vitro neuronal networks provide a simplified model of the central nervous system (CNS) or a specific tissue in CNS, which makes it possible to make inferences about the mechanisms of processes such as as information encoding, plasticity, learning, memory and representation.

Here, we present a new bi-directional experimental setup for controlling neuronal activity in cultured neuronal networks. Electrical activities of neurons and/or neuronal assemblies which are cultured on multi-electrode arrays (MEAs), can be observed in forms of local field potentials (LFPs) and spike streams. In recording path, we employ a 64 channel MEA, which is connected to a preamp with a gain of 1000. Amplified measurements are fed to data acquisition boards and digitized data stream visualized and stored in a graphical user interface (GUI) developed in Matlab. Light patterns or feedback strategies for stimulation are determined within the same GUI as well and send to a digital micro mirror device (DMD) based spatial light modulator (SLM). Stimulation path also incorporates a demagnifying lens for scaling the image projected onto the neurons which results approximately in 10 micrometers resolution.

This work is supported by Bogazici University Research Fund under the Project Code 8080D.

TALK **TUESDAY 2.30PM**

Higher brain functions served by lowly mouse primary visual cortex

Mark F Bear

Department of Brain and Cognitive Science, Picower Institute for Learning and Memory, Massachusetts Institute of Technology, Cambridge, Massachusetts USA

It has been more than 50 years since the first description of ocular dominance plasticity—the profound modification of primary visual cortex (V1) following temporary monocular deprivation. This discovery immediately attracted the intense interest of neurobiologists focused on the general question of how experience and deprivation modify the brain as a potential substrate for learning and memory. The pace of discovery has quickened considerably in recent years as mice have become the preferred species to study visual cortical plasticity, and new studies have overturned the dogma that primary sensory cortex is immutable after a developmental critical period. Recent work has shown that, in addition to ocular dominance plasticity, adult visual cortex exhibits several forms of response modification previously considered the exclusive province of higher cortical areas. These "higher brain functions" include neural reports of stimulus familiarity, reward-timing prediction, and spatiotemporal sequence learning. Furthermore, recent studies have shown that synaptic plasticity within V1 is necessary for both the induction and expression of visual recognition memory. Primary visual cortex can no longer be viewed as a simple visual feature detector with static properties determined during early development. Rodent V1 is a rich and dynamic cortical area in which functions normally associated only with "higher" brain regions can be studied at the mechanistic level.

TALK **WEDNESDAY 2.45PM**

POSTER NUMBER **34**

Age-related corticostriatal decline underlies temporal constraints in action execution

J Bertran-Gonzalez[1], Zala Skrbis[1], Bernard W Balleine[2], Jürgen Götz[1], Miriam Matamales[1]

[1] Clem Jones Centre for Ageing Dementia Research, Queensland Brain Institute, The University of Queensland, Brisbane, QLD, Australia
[2] Brain and Mind Research Institute, The University of Sydney, Camperdown, NSW, Australia

In a similar way to space, estimates of time are a fundamental component of goal-directed learning, and adjustments of the "time of action" play a crucial role in action sequence formation and automatisation. Aged individuals are known to produce deficient action sequences during the acquisition of skills, a deficit that is attributed to malfunction of cortico-basal ganglia circuits. However, the way these processes relate to deficits in time perception remains unknown. Here we investigated the effect of age on goal-directed performance by studying how deficits during action sequence learning related to impaired corticostriatal function. We first analysed the detailed structure of behaviour in aged mice engaged in a fully-automated instrumental task and found severe alterations of action structure as compared to younger controls, which were due to their incapacity to produce action sequences longer than two seconds. Importantly, when animals were forced to extend their time of action, aged mice displayed time-locked patterns of behaviour characterised by compressed ultrafast sequences. Surprisingly, introducing an instructive cue signalling the end of each sequence normalised the time of action, but this effect abruptly disappeared as soon as the cue was removed. Finally, using large-scale functional profiling of neurons, we observed that action-timing defects in the aged specifically correlated with incomplete postero-lateralisation of corticostriatal activity, suggesting aberrant automatisation processes. Altogether, our findings reveal major age-related functional deficits in cortico-basal ganglia networks that correlate with shorter patterns of goal-directed action, a process that likely compromises the ability of older individuals to acquire new skills.

POSTER NUMBER **38**

A stochastic model of IP_3R ion channel gating

Brendan Bicknell

Queensland Brain Institute and School of Mathematics and Physics, The University of Queensland

The inositol triphosphate receptor (IP_3R) ion channel is fundamental to the spatial and temporal regulation of intracellular Ca^{2+} necessary for cell function in many systems. The stochastic De Young-Keizer model has been used widely in theoretical and numerical studies of cell Ca^{2+} dynamics. In this model, each of four identical channel subunits is represented by a continuous time Markov chain with transition rates determined by ligand concentrations and mass action kinetics. The model successfully captures long-time average statistics of experimental data. However, comparison with a recent study shows it is inconsistent with short-time behaviour. This is critical because Ca^{2+} concentrations are dynamic on millisecond timescales, and therefore raises questions about results that were inferred from this foundation. Furthermore, this class of subunit-based models has so far failed to account for the modal gating behaviour observed in IP_3Rs, and many other ion channels.

Here I present a modified De Young-Keizer model that captures both the equilibrium properties and transient behaviour of the IP_3R channel. Ligand independent conformational changes introduce a timescale separation into the kinetics of individual subunits, giving rise to characteristic channel bursting and extended periods of quiescence. A heuristic fit of rate constants using first passage time distributions of the associated aggregated model gives excellent agreement with the experimental data. Modal gating is an emergent statistical feature of the model, arising as a consequence of a slow regulation of the availability of subunits to contribute to channel opening.

TALK **TUESDAY 4.30PM**

Nonlinear, hierarchical dynamics in prefrontal cortex modulate the precision of perceptual beliefs

Michael Breakspear, Matthew Hyett, Christine Guo, Vinh Nguyen

QIMR Berghofer Medical Research Institute.

Actions are shaped not only by the content of our percepts but also by our confidence in them. A decision that depends upon the comparison of two percepts rests upon the representation of stimulus properties and the precision with which each percept is held. To study the cortical representation of perceptual precision and decision making, we acquired functional imaging data acquired whilst participants performed two vibrotactile forced-choice discrimination tasks: a fast-slow judgement, and a same-different judgement. Whereas the first task only requires a comparison of the perceived vibrotactile frequencies, the second requires that the estimated difference between those frequencies be weighed against the precision of each perceptual representation. We report a constellation of cortical regions in rostral prefrontal cortex, dorsolateral prefrontal cortex and superior frontal gyrus associated with these operations. Dynamic causal modelling (DCM) of these data identified a nonlinear model, embodying a hierarchy of processing from the inferior parietal lobule through to the superior frontal gyrus. This model of effective connectivity outperformed competing models with serial and parallel interactions hence providing a unique insight into the hierarchical architecture underlying the representation and appraisal of perceptual belief and precision in prefrontal cortex.

POSTER NUMBER **39**

Quantitative analysis of axonal branch dynamics in the developing retinotectal system

Kelsey Chalmers[1], Elizabeth M Kita[1], Ethan K Scott[2], Geoffrey J Goodhill[1,3]

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[2] School of Biomedical Sciences
[3] School of Mathematics and Physics
The University of Queensland.

Branching is an important mechanism by which axons navigate to their targets during neural development. For instance, in the developing zebrafish retinotectal system, selective branching plays an important role both during both initial pathfinding and subsequent arborization once the target zone has been reached. Here we show how quantitative methods can help extract new information about the nature of the underlying branch dynamics from timelapse imaging. First, we introduce Dynamic Time Warping to this domain as a method for automatically matching branches between frames, replacing the effort required for manual matching. Second, we model branch dynamics as a birth-death process, i.e. a special case of a continuous-time Markov process. This reveals that the birth rate for branches from zebrafish retinotectal axons increases over time, but the death rate remains constant. Furthermore blocking activity with TTX increases the death rate, but leaves the birth rate unchanged. Third, we show how the extraction of these rates allows computational simulations of branch dynamics whose statistics closely match the data. Together these results reveal new aspects of the biology of retinotectal pathfinding, and introduce computational techniques which are applicable to the study of axon branching more generally.

POSTER NUMBER **4**

Audiovisual integration in areas MT & MST of marmoset monkeys

Chaplin TA[1,2,3,4], Allitt BJ[1,2,4], Hagan MA[1,2,4], Price NS[1,2,3,4], Rosa MGP[1,2,3,4], Rajan R[1,2,3,4], Lui LL[1,2,3,4]

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[3]Monash Vision Group, Monash University
[4]Centre of Excellence for Integrated Brain Function, Monash University

Recent studies have shown anatomical and physiological evidence for multisensory integration in brain regions that have been historically classed as unisensory. In the cerebral cortex of monkeys, areas MT and MST have well known roles in processing visual motion, and in marmosets, these areas have direct connections with auditory cortex (more prominent in MST than MT). Yet, no study to date has found auditory stimuli to influence single cell activity in primate MT or MST. We performed extracellular recordings (n = 122, 72 in MT, 50 in MST) in 2 anaesthetised marmosets using linear arrays and tested whether neurons can integrate auditory and visual motion cues. Visual stimuli were random dot kinematograms moving either left or right at a range of motion strengths. Auditory stimuli were interaural level difference ramps of 6-12kHz bandpass noise presented with headphones, which simulated auditory motion along the azimuth. No neuron in either area was responsive to auditory stimuli alone, but in MST spike rates were slightly higher in the audiovisual condition compared to the visual only condition ($p=0.01$). This meant that the addition of auditory stimuli allowed greater detectability of motion by single neurons ($p=0.002$), and also improved neurons' ability to discriminate opposite directions of motion ($p=0.03$). In contrast, MT did not show consistent changes in firing rates or improved detectability/discriminability in the audiovisual condition. These modulations of MST neurons are consistent with human behavioural results where visual motion detection thresholds are improved with a moving auditory stimulus.

TALK **THURSDAY 11.45AM**

Probabilistic learning by rodent grid cells

Allen Cheung

Queensland Brain Institute, The University of Queensland

Mounting evidence shows that mammalian brains are probabilistic computers, but the specific cells involved remain elusive. Parallel research shows that entorhinal grid cells are fundamental to spatial cognition but their diverse response properties still defy coherent explanation. Here, electrophysiological and theoretical evidence is presented which shows that grid cell responses are accurately predicted by probabilistic learning computations. Diverse response properties of probabilistic grid cells were statistically indistinguishable from rat grid cells across key manipulations. A simple coherent set of probabilistic computations explains stable grid fields in darkness, partial grid rescaling in resized arenas, low-dimensional attractor grid cell dynamics, and grid fragmentation in hairpin mazes. These findings provide a simple and unified explanation of grid cell function, and point to grid cells as an accessible neuronal population involved in probabilistic computations.

POSTER NUMBER **33**

Isoflurane anesthesia reduces coherence in the central fly brain

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[2]Queensland Brain Institute, The University of Queensland, Brisbane, Australia
[3]Monash Institute of Cognitive and Clinical Neuroscience, Monash University, Australia

General anesthesia reduces the levels of consciousness in humans and animals alike, yet exactly how it affects the neural representation of external stimuli remains poorly understood. Under anesthesia neural activity is generally thought to be reduced, but external stimuli still reliably evoke responses. Here we tested how isoflurane anesthesia affects the neural responses to a visual stimulus in the simpler and smaller brains of fruit flies. We presented flickering visual stimuli (e.g., 13 or 17Hz) and varied the concentration of isoflurane while recording Local Field Potentials (LFP) from a linear multi-contact electrode. By focusing on the flicker-evoked responses in the frequency domain, we assessed how isoflurane affects evoked power and coherence in central and peripheral brains areas. We found that isoflurane reduced power and coherence at the tagging frequency (13 or 17Hz) in central brain regions, but in contrast increased power and coherence at peripheral areas at the second harmonic (26 or 34Hz). To better understand this dissociation we constructed a simple model based on the separation of visual processing into brightness increment (ON) and decrement (OFF) responsive pathways. Our model suggests that the increase in power in peripheral areas can be understood in terms of the isoflurane-effected responses of these two pathways. The coherence findings can be explained in the same framework through the incorporation of noise. Our model further highlights the importance of the physiological substrate in the interpretation of the spectral features, and that changes in power and coherence are extremely sensitive to the local characteristics of the LFP.

POSTER NUMBER **28**

Intra-cortical excitatory circuitry innervating layer 6 pyramidal neurons of the rat primary visual cortex

Florence Cotel[1], John Apergis-Schoute[2], Simon De Croft[1], Stephen Williams[1]

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[2] Department of Phamacology - University of Cambridge, Cambridge, UK

Layer 6 projection neurons powerfully influence neocortical information processing through the control of local intracortical circuitry, and subcortical targets. Morphologically distinct classes of layer 6 projection neurons have been identified in the visual cortex, but little information is available on the intracortical circuitry that drives these neuronal classes. To address this we made whole-cell recordings from identified layer 6 projection neurons maintained in acute slice preparations of rat primary visual cortex. Morphologically, layer 6 pyramidal neurons retrogradely-filled from the visual thalamus exclusively possessed short apical dendritic arbors that terminated within layer 4. In contrast, the apical dendritic arbor of non-cortico-thalamic layer 6 projection neurons spanned the neocortical layers terminating in a simple tuft at the base of layer 1. The somatically recorded intrinsic electrical properties of these neuronal classes were indistinguishable. Paired recordings however revealed that cortico-thalamic and non-cortico-thalamic layer 6 pyramidal neurons were sparsely and reciprocally interconnected by distributed excitatory synapse contacts which exhibited cell-class specific, but not target-cell-dependent, rules of use-dependent facilitation and depression. Trans-laminar excitation to either class of layer 6 projection neuron from presynaptic layer 2/3 or layer 5 pyramidal neurons was undetectable, however we observed a powerful and reliable cell-class specific excitatory input from layer 4 star pyramidal neurons to non-cortico-thalamic layer 6 pyramidal neurons. Furthermore, minimal layer 1 electrical stimulation evoked monosynaptic excitatory synaptic input exclusively in non-cortico-thalamic layer 6 pyramidal neurons. Together these data reveal that layer 6 projection neurons are embedded in cell-class specific excitatory neuronal networks in the primary visual cortex.

POSTER NUMBER **15**

A comparison of the computational methods of burst analysis in neuronal spike trains and their application to recordings of human stem cell-derived neuronal networks

Ellese Cotterill[1], Paul Charlesworth[2], Ole Paulsen[2], Stephen J Eglen[1]

[1]Cambridge Computational Biology Institute, University of Cambridge
[2]Department of Physiology, Development and Neuroscience, University of Cambridge

The tendency of neurons to fire bursts of action potentials has been associated with many physiological processes, including information processing and long-term potentiation. Precise identification of periods of bursting activity thus plays a critical role in many applications, such as the accurate quantication of time course changes in network behaviour during development, or as a result of pharmacological or genetic manipulations. Microelectrode array (MEA) recordings of cultured neuronal networks are a common and efficient means of studying this bursting activity *in vitro*. To address the problem of accurate identi_cation of bursts, a large number of burst detection techniques have been proposed, many of which have been developed and verified based on MEA recordings from rodent nervous systems. Recently, human stem cell-derived neuronal networks cultured on MEAs have been shown to exhibit spontaneous bursting activity. There is thus a demand for a robust method of analysing bursting in these networks, which commonly exhibit more variable and complex patterns of bursting activity than rodent neuronal networks. Using both synthetic and experimental data, we assessed the performance of a number of existing burst detection techniques at identifying bursts in spike trains with properties resembling those of human neuronal network recordings. We identify a number of issues with common burst detection techniques, and provide recommendations regarding the best approaches to comprehensive burst analysis of experimental data. These practices are then used to examine the ontogeny of bursting activity in networks of human induced pluripotent stem cell-derived neurons.

TALK **THURSDAY 9.00AM**

Neural circuits for sleep control

Yang Dan

University of California, Berkeley, USA

The neural circuits controlling sleep and wakefulness are distributed in the basal forebrain, hypothalamus, and brainstem. Each brain region contains multiple cell types with intricate synaptic interactions through both local and long-range connections, but the specific roles played by each neuronal type remains unclear. Using optogenetic manipulation, behavioral measurements, electrophysiological recording, imaging, and virus tracing, we define the functional properties and connectivity of different cell types in these regions underlying wake, rapid-eye-movement (REM) sleep, and non-REM sleep.

POSTER NUMBER **13**

Radial orientation selectivity in Linsker-type learning network

Catherine E Davey[1], David B Grayden[1], Anthony N Burkitt[1]

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Learning and memory are crucial functions of the brain. Synaptic plasticity is an important mechanism for learning, in which neuronal connection strengths are modified in response to environmental inputs [1]. By identifying the general principles of plasticity in neural networks, we can gain insight into the learning process. Learning begins prior to birth, so we know that cortical structure is created in the absence of structured input. In a three-paper series, Linsker proposed a mechanism by which learning may occur prenatally [2,3,4]. This model demonstrated that spatial structure in synaptic connectivity prompts the evolution of circularly symmetric cells, in a system driven only by noisy input [2]. Additionally, the model showed that orientation selective cells may develop by the sixth layer of processing [3]. However, the resulting orientation selectivity was found to be random, being a function of stochastic weight initialisations [5]. Radial selectivity, in which cells are found to have an orientation selectivity biased towards a central point, has been observed in several cortical structures, including the visual cortex [6] and the auditory cortex [7]. Our work shows how plasticity can evolve radial orientation selectivity in the absence of structured input. We propose a modified network in which synaptic density is a function of a cell's radial distance from the layer centre, remaining faithful to Linsker's objective of a minimal set of assumptions to establish general principles of plasticity. The proposed network provides for larger receptive fields for increasingly distal cells in the laminar structure. Our results demonstrate, both analytically and computationally, how neurons in the third layer of processing can predictably develop radial orientation selectivity. The mechanisms developed in this study could play a central role in the development of radial orientation selectivity in the visual cortex.

Acknowledgements

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References

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TALK **WEDNESDAY 9.00AM**

Heuristics of control: habitization, fragmentation, memoization and pruning

Peter Dayan

Gatsby Computational Neuroscience Unit, University College London

Goal-directed or model-based control faces substantial computational challenges in deep planning problems. One popular solution to this is habitual or model-free control based on state-action values. In a simple planning task, we found evidence for three further heuristics: blinkered pruning of the decision-tree, the storage and direct reproduction of sequences of actions arising from search, and hierarchical decomposition. I will discuss models of these and their interactions. This is work with Quentin Huys in collaboration with Jon Roiser and Sam Gershman.

TALK **WEDNESDAY 10.15AM**

POSTER NUMBER **31**

Learning state-space representation and hierarchical decision-making in rats

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Evidence indicates that goal-directed actions, i.e., actions that are taken by an agent to attain a certain goal, are crucial components of decision-making processes in animals and humans. The source of these actions is suggested to be a model-based reinforcement learning system in the brain, which learns the contingencies between actions and the states of the environment. Such a decision-making process, however, requires an agent to firstly learn the correct representation of the task space, and secondly, hierarchically organize actions in order to make goal-directed decision-making scalable to multi-stage and complex environments. Here, using a sequential decision-making task in rats, we firstly show that the profile of choices made by animals reveals a gradual shift from a simple representation of the task space, to a more complex form, which matches the true sequential structure of the task; and secondly, we show that within this multi-stage representation, animals engage in a hierarchical model-based decision-making process. Furthermore, results of a Bayesian model comparison procedure, consistent with the behavioral results, confirm that animals are using hierarchical model-based reinforcement learning. Therefore, we provide evidence supporting the hypothesis that, the decision-making processes in the brain can be conceptualized using model-based hierarchical reinforcement learning, and we also provide a new experimental protocol in rats, which can be used to measure the operation of these decision-making processes.

POSTER NUMBER **16**

Retinal Population codes are influenced by field shaping under suprachoroidal stimulation

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Visual prostheses are at the cutting edge of functional electrical stimulation, as our experience with cochlear implants is turned to restoring a functional sense of vision to the blind. However, like all neurostimulators, visual prostheses are subject to many limitations. Using an in-vitro model of a suprachoroidal retinal prosthesis, we set out to explore a family of techniques which has been used to improve the quality of therapy delivered by other neurostimulators — field shaping. Multi-unit activity from the retinal ganglion cell layer of a small number of isolated rabbit retina was recorded using a 60-electrode multi-electrode array (MEA), while different configurations and amplitudes of bipolar and tripolar current-electrical stimuli were delivered suprachoroidally. The local population responses to different configurations of stimulus show differences in both minimum stimulus threshold and maximum spike-rate dependent on the local return configuration. Since the lower bound on the performance of many neural codes can be approximated by the performance of a naïve Bayesian classifier, such a classifier was trained on the trial-averaged spike-rates across channels, as well as on trial spike-rates for individual stimulus presentations. In both cases, this simple model can predict the configuration of local returns for novel supra-threshold stimuli at a rate significantly greater than chance – 6-10× chance for trial-averaged spike-rates ($p < 0.05$) and 3× chance for individual trial spike rates. Consequently, it would be expected that patients using a suprachoroidal visual prosthesis would also be able to distinguish between the percepts delivered through different configurations of local returns.

This research was supported by the Australian Research Council (ARC) through its Special Research Initiative (SRI) in Bionic Vision Science and Technology grant to Bionic Vision Australia (BV A).

TALK **THURSDAY 12.15PM**

POSTER NUMBER **65**

Salience invariance with divisive normalisation in higher-order insect neurons

Bernard JE Evans[1], David C O'Carroll[1,2], Steven D Wiederman[1]

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[2] Department of Biology, University of Lund

A common trait in sensory processing is the filtering and extraction of salient higher-order stimulus components such as features or local motion, using nonlinear operations that confound desired information with extraneous factors, such as, feature contrast and angular size.

Here we present a feasible method for establishing precise positional information of a moving target, that is invariant to contrast, size and velocity. Our model produces a monotonic relationship between position and output activity (spike rate) using a divisive normalization between two overlapping, wide-field, 'small-target motion detector' (STMD) neurons. Each individual STMD's responsiveness to target contrast, size and velocity is, in effect, cancelled out. We used evolutionary programming to simulate effects of divergence in receptive field size and shape over time and the likelihood that such a system could exist over multiple generations. With appropriate fitness functions, candidate receptive fields converged to produce a parameter invariant, estimate of position robust to the addition of noise. We found that attributes observed in physiological responses, such as high spontaneous activity and thresholding non-linearities actually enhance the positional signal-to-noise. This mechanism for establishing salience-invariant position may have significant explanatory power in insect-systems where higher-order neurons, found further along the processing chain combine many input parameters leading to greater ambiguity and apparently losing precise position information. This model helps reconcile behavioural studies (where insects appear to have precise positional estimation during steering) and neuronal physiology (where cells appear to confound many attributes of the input) and contributes to the development of robust target tracking systems.

POSTER NUMBER **29**

Rostro-caudal gradient of the dendritic integrative properties of layer 5 pyramidal neurons across the primary visual cortex

Lee N Fletcher, Stephen R Williams*

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The thickness of the neocortex varies over the neocortical mantle, a property that determines the size of the dendritic arbor of neurons. In order to preserve neuronal-class properties across the neocortex, the electrical architecture of the dendritic arbor must be scaled to parallel such morphological changes and maintain computational features. The conservation of the integrative properties of a defined class of neuron with dendritic size has, however, not been directly explored. Layer 5B pyramidal neurons integrate synaptic input from all layers of the cortex and are a major output neuron of the cortex. Among other neuronal populations, they have been shown to exhibit computationally powerful, domain specific integration of synaptic input within their dendritic arbor. Here we use high-resolution anatomical reconstruction, multi-site somato-dendritic electrophysiological recordings and computational modelling approaches to demonstrate that the physical size, electrotonic architecture, and mode of dendritic integration of layer 5B pyramidal neurons vary as a gradient across the rostro-caudal axis of the rat primary visual cortex. Our findings reveal the integrative capacity of layer 5B pyramidal neurons transforms from multi-compartment, layered computations, to compact axo-somatic integration across the primary visual cortex. These data challenge the view that neocortical neuronal populations carry out stereotyped, canonical computations within repeated microcircuits.

TALK **WEDNESDAY 11.00AM**

Predictive and efficient coding in sensory learning

Marta I Garrido

Queensland Brain Institute and Centre for Advanced Imaging, The University of Queensland

The ability to learn about regularities in the environment and to make predictions about future events is fundamental for adaptive behaviour, as it may provide a competitive advantage for anticipating reward or avoiding punishment. In this talk I will demonstrate that: 1) people are able to encode statistical regularities in the sensory environment, 2) violations to these regularities evoke sensory prediction errors that engage fronto-temporal networks with recurrent interactions, and that 3) these networks may be disrupted when predictive processes go awry.

POSTER NUMBER **51**

The effects of attention on neural representations of environmental statistics

MI Garrido[1,2,3], EG Rowe[1,2], V Halasz[1,2], JB Mattingley[1,3,4]

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[4]School of Psychology, The University of Queensland, Australia

Predictive coding posits that the human brain is a predictive machine that continually monitors the environment for regularities and detects inconsistencies. It is unclear, however, what effect attention has on these processes. Attention is known to enhance neural responses, whilst prediction attenuates them; with little research and contradictory findings examining the interaction between the two. Here, we investigated the effects of selective spatial attention and predictability on brain dynamics and behaviour. We designed a novel binaural auditory oddball task where participants were required to attend to (and detect targets in) an auditory stream. Oddball tones were either present in the side of the attended ear, or played to the contralateral ear. Participants were asked to attend to the auditory streams in either one or both ears. Behavioural results showed we successfully manipulated the focus of attention, with faster reaction times and more errors made in the bilateral attention condition. We observed sensory prediction error responses, across each and all attentional manipulations. We found a larger prediction error in the attended condition at 45ms and 305ms over frontal and central channels, respectively. Smaller prediction errors were observed at 215 ms over frontal channels when attention was divided. However, this effect was reversed at 285 ms over central channels. Source reconstruction revealed a fronto-temporal network for MMN across all attentional levels. Furthermore, we found a trend for an interaction between attention and deviance in the inferior temporal lobe. Our results demonstrate that attention modulates the neural representations of prediction errors differently across different time points and brain regions.

POSTER NUMBER **1**

Faster responses under low-contrast stimulation in rat V1

Masoud Ghodrati, Dasuni Sathsara Alwis, Nicholas Seow Chiang Price

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Orientation selectivity is a fundamental characteristic of neurons in mammalian primary visual cortex (V1). Orientation selectivity is invariant to stimulus contrast and luminance, which are two basic properties of visual stimuli in the natural world. Under low light or contrast levels (e.g. in fog), driving and games involving hand-eye co-ordination become more difficult, suggesting that the time-course of orientation processing is affected by contrast and luminance. However, no studies have investigated this time-course. Here, we characterised the dynamics of orientation selectivity in rat V1 neurons (N=268) using a reverse correlation method. We recorded neuronal activity from anesthetized rats, using multi-electrode arrays, while animals were presented a movie of sinusoidal gratings (each visible for 33 ms) with continually changing orientation, phase, and spatial frequency. In different stimulus blocks, we varied luminance and contrast. Orientation selectivity was evident from 60±23 ms, with peak selectivity at 80±20 ms post stimulus onset. Orientation selectivity was invariant in different luminance-contrast conditions, confirming previous reports. Although neurons responded earlier with higher luminance stimuli, the response latency to high-contrast gratings was surprisingly longer than to low-contrast stimuli. Information theoretic analysis also showed that the visual information carried by neurons is the same in all conditions. Based on our computer simulations, we suggest that the longer latencies in high-contrast conditions are due to membrane hyperpolarization after prolonged exposure to high-contrast stimuli. The hyperpolarization at high-contrast may increase signal-to-noise ratios while a more depolarized membrane under low-contrast may lead to greater sensitivity to weak stimuli.

POSTER NUMBER **43**

A phase transition in human brain connectivity

Leonardo L Gollo, James A Roberts, Michael Breakspear

Systems Neuroscience Group, QIMR Berghofer Medical Research Institute

The acquisition of high-quality tractography data acquired non-invasively from large numbers of healthy humans has placed connectomics at the center of systems neuroscience research. A number of important features of the human connectome have been identified, such as its small world topology and rich club backbone. However a general theoretical framework is still missing. Recent work suggests that the geometry of the brain (its spatial embedding) explains much, but not all, of the topological structure of the connectome. Percolation theory is an insightful way to analyze how connectivity emerges in large complex networks. Here, we use the tools of percolation theory to understand the "gap" between geometry and topology. We find a so-called percolation transition between empirically observed brain networks and those predicted by geometry alone. This suggests that the additional topology that the brain is imbued with, on top of its geometry, plays an important role in information segregation and integration.

POSTER NUMBER **24**

Optogenetics reveals asymmetrical GABAergic recruitment within the lateral amygdala by auditory inputs

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The amygdala is a collection of functionally discrete, though complexly interconnected nuclei, which is critical for the acquisition and storage of emotional memory. Also known as associative memory, this higher-order cognitive function involves the pairing of environmentally derived sensory information, to produce learned behavioural responses. Previous investigation into associative learning is primarily centred on the behavioural learning paradigm fear conditioning, or its translational electrophysiological in vitro models. However, our present understanding of this structure is restricted by the limitations of conventional electrophysiological techniques, and the underlying neuronal circuits remain to be fully elucidated. Here, using virally targeted optogenetic stimulation with acute slice electrophysiology, we confirm that principal neurons (PN) of the lateral amygdala (LA) receive direct and robust inputs from both the auditory thalamus (AT) and auditory cortex (AC). However, in contrast to earlier findings, input specific stimulation revealed an asymmetrical recruitment of local GABAergic circuits between the AT and AC, indicated through altered disynaptic inhibition upon LA PN. Further, discrepancies were revealed between electrical and optogenetic stimulation of AT terminals within the LA. We present evidence to suggest that electrical stimulation of the classical cortical and thalamic input sites of the LA is not input-restricted, and can instead produce the undetectable co-activation of these reciprocally connected AT and AC afferents. This study reveals input-specific circuit recruitment and information processing within the amygdala during auditory innervation, masked by conventional methods, with consequences for current models of emotional memory.

TALK **THURSDAY 3.00PM**

Coding and plasticity in visual maps

Geoffrey J Goodhill

Queensland Brain Institute and School of Mathematics and Physics, The University of Queensland

Topographic maps are common throughout the nervous system. I will discuss our two recent studies investigating (1) the role of topographic maps in sensory decoding, and (2) their degree of plasticity in response to the statistics of the environment.

(1) Is the topography of the map from the retina to the tectum actually required for the spatial locations of objects in the visual field to be determined from tectal activity? We recorded population activity from the larval zebrafish tectum in response to visual stimuli at different locations in the visual field. We then asked how accurately stimulus location could be decoded from this activity. A decoder based on the topographic location of the activity performed quite poorly. However a maximum likelihood decoder, ignoring the locations of neurons in the map, performed very well. Thus, the retinotectal map in zebrafish is neither required for stimulus decoding, nor does it provide a particularly effective method for achieving this.

(2) Orientation preference (OP) maps in the primary visual cortex of cats and monkeys are characterised by pinwheels, where all orientations meet at a point. While some aspects of this mapping can be altered by sensory experience, current evidence suggests that pinwheel positions arise through innate mechanisms. By raising cats wearing cylindrical lenses, biasing input in the left and right eyes to horizontal and vertical orientations respectively, we found that this altered visual input during development caused a repositioning of OP pinwheels relative to ocular dominance columns, consistent with a theoretical prediction based on Hebbian learning principles. Thus, map relationships in primary visual cortex adapt to the statistics of visual input on developmental timescales.

POSTER NUMBER **5**

Response properties of MT neurons to random dot motion stimuli after V1 lesion

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Damage to the Primary Visual Cortex (V1) results in a scotoma in the corresponding parts of the visual field, where conscious vision is no longer experienced. However, patients often retain some unconscious visual faculties within the scotoma, a phenomenon known as "blindsight."

The Middle Temporal Area (MT), which is important for processing of complex motion in primates, is thought to be critical for blindsight. Electrophysiological studies have shown that MT neurons continue to respond to moving stimuli inside the scotoma. However, no study has quantitatively measured the motion sensitivity of neural responses to random dot stimuli in area MT in any primate species after long-standing V1 lesions.

We recorded 93 MT cells in two anesthetized adult marmosets (45 cells in monkey 1; 47 cells in monkey 2), 10-11 months following a unilateral, partial V1 lesions. The size and location of the scotoma was determined by recording from V1 neurons around the lesion border. The receptive fields of MT cells in the lesion projection zone were significantly distorted compared to those outside this zone ($p<0.001$, Wilcoxon's rank sum). This was quantified by comparing the Gaussian peak of each receptive field to its centre of mass. In addition, there was a significant decrease in the proportion of MT neurons that were direction selective. These results suggest that long after V1 lesions, MT undergoes substantial reorganization. The decrease in the proportion of direction selective MT cells may explain the compromised omplex motion perception associated with blindsight.

POSTER NUMBER **46**

Alpha and theta oscillations play dissociable roles in goal-directed attention

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The ability to flexibly orient to goal-relevant stimuli necessarily requires the interaction of feedforward and feedback cortical activity. Recent work in non-human primates has characterised distinct oscillatory frequencies as carrier signals for feedforward and feedback information. Theta and gamma oscillations have been identified as preferentially associated with the feedforward flow of information, while alpha/beta oscillations have been associated with feedback information. Here we investigated the roles of theta and alpha oscillations in goal-directed visual attention, and asked whether their involvement is consistent with their putative roles as carriers of feedforward and feedback information. We had participants respond to a target of a particular colour among heterogeneously coloured distractors. Prior to the appearance of the target display we cued one location with a nonpredictive cue that was either target- or nontarget-coloured. To map alpha and theta activity in response to these cues we recorded EEG and behavioural responses. We found that theta oscillations became lateralised early and in response to all cues. This lateralisation was larger, however, if the cue matched the target colour, consistent with feature-based enhancement of the feedforward signal. Alpha oscillations became lateralised later, and only in response to target-coloured cues, consistent with what is known about the behaviour of spatial attention under these conditions. These results demonstrate the involvement of theta and alpha oscillations in goal-directed attention, and are consistent with the hypothesised roles of theta and alpha oscillations as carrier frequencies for feedforward and feedback signals, respectively.

POSTER NUMBER **32**

CA1 neuronal dysfunction results from hyperphosphorylated tau impairing axon initial segment activity and location.

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The hippocampus plays an important role in memory formation and is affected by early degenerative changes during the course of Alzheimer's disease (AD), suggesting that it has a role in the etiology of this disease. Transgenic rTg4510 mice that harbour the P301L human tau mutation recapitulate aspects of AD, including impaired spatial memory and hippocampal long-term potentiation. Histopathologically, hyperphosphorylated tau (p-tau) and neurofibrillary tangles are observed in transgenic rTg4510 mice and pR5 mice, which also harbour the P301L mutation. Previously p-tau has been reported to impair the structure of the axon initial segment (AIS), the neuronal compartment that generates AP. However, little is known about how and when hippocampal neuron activity is affected in mouse models of AD. We show here that from 1-2 months of age p-tau levels were increased and CA1 pyramidal neuron action potential (AP) firing and AP amplitude were reduced in rTg4510 mice compared to wild-type mice. Peak AIS voltage-acceleration was also reduced at 1-2 months of age, whereas somatic voltage-acceleration was increased. Neuronal degeneration only became evident at 12-14 months. Reduced AP firing, AP amplitude and AIS voltage-acceleration was also observed in 18 month old pR5 mice compared to wild-type mice. Furthermore, transfection with pseudo-phosphorylated human tau in primary hippocampal neuronal cultures also reduced AIS voltage-acceleration. Interestingly, preliminary data indicates that p-tau reduces neuron activity by movement of the AIS down the axon away from the soma. These data suggest a novel mechanism for how p-tau impairs hippocampal neuronal activity in AD.

POSTER NUMBER **47**

Functional brain networks underlying high-level cognitive reasoning and fluid intelligence

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Our capacity for higher cognitive reasoning – often known as fluid intelligence – allows us to understand complex and abstract ideas. Classical neuropsychological studies have identified the frontal lobes as being critical for reasoning abilities, but more recent network-based analyses of functional brain imaging data have revealed the importance of functional interactions across a wide range of cortical and subcortical areas in the service of fluid intelligence. To better understand the nature of these interactions, we collected fMRI data at 7T to maximize both temporal and spatial resolution, in a cohort of 60 healthy adult participants who also underwent standard intelligence testing. Neural activity was measured during the performance of a non-verbal reasoning task akin to Sudoku, known as the Latin Square Task. As expected, participant accuracy scaled with reasoning complexity, such that performance declined with increments in the number of elements to be related within a trial. Brain activity within canonical 'task-positive' brain regions increased parametrically with task complexity, whereas 'task-negative' regions showed a stepwise decrease in activity as task complexity increased. Network analyses of task-related changes in connectivity revealed significant interactions between regions comprising the fronto-parietal, cingulo-opercular, and default-mode networks in association with increased task demands. Our results suggest that patterns of cooperation and competition within and across large-scale networks are key predictors of reasoning performance, as well as more global intelligence measures.

POSTER NUMBER **40**

Multiple cortical feature maps in a joint Gaussian process prior

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The topographic arrangement of edge orientation preference in the mammalian primary visual cortex is a striking example of cortical organisation, and the structure of these feature maps have remarkably consistent statistical properties across species. However, fine scale analysis of this organisation requires the accurate reconstruction of maps from inherently noisy imaging data. Recently a new method was introduced for solving this problem using Bayesian Gaussian process methods to reconstruct orientation preference maps more accurately than classical techniques, by explicitly encoding known properties of map structure. However, so far this work has ignored the several maps for other features of visual input, such as the eye of origin and spatial frequency, which coexist with the orientation preference map, and which have mutually dependent spatial arrangements. While these relationships have been described empirically, a formal mathematical approach is currently lacking. Here we present a substantial extension of the Gaussian process framework which considers multiple maps simultaneously. We demonstrate that this model allows for improved reconstruction of multiple maps compared to classical techniques, can encode the empirically observed relationships, and that it is easily extended to include any number of maps and their relationships. This provides the first rigorous and principled approach to the theoretical

TALK **WEDNESDAY 3.30PM**

SK channels and spike-timing dependent plasticity

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Small conductance calcium-activated potassium channels (SK channels) are present in spines and can be activated by EPSPs and backpropagating action potentials (APs). This suggests they may play a critical role in spike-timing dependent synaptic plasticity (STDP). In my lecture I will discuss recent data showing that SK channels on dendritic spines are activated by APs and suppress EPSPs in cortical and hippocampal pyramidal neurons. In cortical pyramidal neurons EPSP suppression by backpropagating APs depended on their precise timing, was dendritic in origin, and involved SK-dependent suppression of NMDA receptor activation. Finally, we show that SK channel activation by APs blocks STDP induction during low-frequency single AP-EPSP pairing, with both LTP and LTD absent under control conditions but present after SK channel block. These data indicate that SK channel activation by APs suppress EPSPs and gates STDP induction in pyramidal neurons.

POSTER NUMBER **8**

Retinal ganglion cells: mechanisms underlying depolarization block

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Retinal ganglion cells (RGCs) are known to have non-monotonic responses to increasing amplitudes of high frequency (2 kHz) biphasic electrical stimulation. That is, an increase in stimulation amplitude causes an increase in the cell's spike rate up to a peak value above which further increases in stimulation amplitude cause the cell to decrease its activity. The peak response for ON and OFF RGCs occurs at different stimulation amplitudes, which allows differential stimulation of these functional cell types. In this study, we investigate the mechanisms underlying the non-monotonic responses of RGCs.

Using in vitro patch-clamp recordings from rat RGCs, together with simulations of single and multiple compartment Hodgkin-Huxley models, we show that the non-monotonic response to increasing amplitudes of stimulation is due to depolarization block, a change in the membrane potential that prevents the cell from generating action potentials. We show that the onset for depolarization block depends on the amplitude and frequency of stimulation and reveal the biophysical mechanisms that lead to depolarization block during high frequency stimulation.

Our results indicate that differences in transmembrane potassium conductance lead to shifts of the stimulus currents that generate peak spike rates. We also show that the length of the axon's high sodium channel band (SOCB) affects non-monotonic responses and the stimulation amplitude that leads to the peak spike rate.

These results may have important implications for stimulation strategies in visual prostheses.

TALK **TUESDAY 5.15AM**

POSTER NUMBER **17**

The decoding of slowing adapting afferents: a Bayesian approach

Patrick Kasi[1], James Wright[1], Heba Khamis[2], Ingvars Birznieks[1,3,4], André van Schaik[1]

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Tactile signals carry information that is relevant for precise object manipulation in humans. It is therefore essential to devise decoding methods to extract information as means to gain some insight into the fundamental sensory mechanisms that underlie dexterous object manipulation in humans. Aside from using decoding algorithms to study how populations of neurons represent information, decoding algorithms may portend ideas through which we can design sensory-controlled biomedical devices and robotic manipulators. In this study, we use a two-stage nonlinear decoding paradigm to reconstruct the force stimulus given signals from slowly adapting type one (SA-I) tactile afferents. First, a learning procedure—inhomogeneous Poisson process encoding model—is developed. In this simple implementation, a mapping between the force stimulus and its first derivative, and the neural spike activity is estimated. In a second phase, we use a point process stochastic filter (Bayesian filter for binary data) to reconstruct the force profile, given the SA-I spike patterns and parameters described by the encoding model. We also assess three candidate inhomogeneous Poisson process encoding models using Akaike's Information Criteria (AIC). Under the current encoding model, the model that considers force and the force derivative performed the best. The framework used in this study provides a good quantitative methodology to study tactile afferents. It is also advantageous because it is flexible, and improvements can be made that would describe the SA-I data better.

POSTER NUMBER **56**

Perceptual confidence demonstrates trial-by-trial insight into the precision of audio-visual timing encoding

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Peoples' subjective feelings of confidence typically correlate positively with objective measures of task performance, even when no performance feedback is provided. This relationship has seldom been investigated in the field of human time perception. Here we confirm findings suggestive of a positive relationship between the precision of human timing perception and decisional confidence. We first demonstrate that subjective audio-visual timing judgements are more precise when people report a high, as opposed to a low, level of confidence. We then find that this relationship is more likely to result from variance in sensory timing estimates than the application of variable decision criteria, as the relationship holds when we adopted a measure of timing sensitivity designed to limit the influence of subjective criteria. Our results suggest analyses of timing perception and associated decisional confidence can be used in conjunction to estimate the trial-by-trial variability with which timing has been encoded.

POSTER NUMBER **50**

Connectivity based parcellation of basal ganglia functional zones using diffusion-weighted MRI tractography

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In neurological disorders such as Parkinson's disease, correct functioning of the basal ganglia circuitry is compromised, resulting in patients suffering from movement-related and cognitive impairments. Structural mapping could give valuable insight into the functional organisation of the basal ganglia and provide useful information to help understand the pathophysiological processes associated with diseases involving basal ganglia functional impairment.

Here, we use diffusion-weighted magnetic resonance imaging (dMRI) tractography in 20 healthy subjects to examine the connectivity of the main functional circuits of the basal ganglia. Connectivity between basal ganglia nuclei and motor cortex, frontal cortex, parietal cortex, occipital cortex and temporal cortex was examined. Basal ganglia structures were parcellated based on their connectivity to cortical target regions in all subjects and the resulting connectivity maps were averaged in a study specific template space. Preliminary results suggest, that the functional organisation of the basal ganglia is consistent across individuals and follows a general rostro-caudal/ventro-lateral pattern. While some regions are predominantly connected to a single cortical target, other areas within the basal ganglia show overlapping connections with multiple cortical areas. Our preliminary connectivity based parcellation maps presented here are in line with previous dMRI studies using similar techniques and in accordance with anatomical tracer studies in animals. We believe that our method is useful for studying disorders affecting basal ganglia networks and could facilitate treatments that directly target basal ganglia structures, such as deep brain stimulation.

POSTER NUMBER **64**

Fly-ing in a virtual arena: flight thrust and body streamlining dynamics of flies

Kiaran Lawson

Queensland Brain Institute, The University of Queensland, Australia

Insects are magnificent fliers which can perform many complex tasks in air, such as collision avoidance, speed regulation and smooth landings, even though their computational abilities are limited by their extremely small brain. To investigate how flying insects respond to changes in wind speed and surrounding optic flow, female Queensland fruit flies (*Bactrocera tryoni*) were tethered to a metal rod and flown in a virtual reality arena.

The virtual reality setup exposed the flies to sinusoidally oscillating inputs of optic flow (simulated by 4 monitors surrounding the fly) and headwind (generated by a frontal fan). Inputs were oscillated at 4 frequencies ranging between 1/32 to 1/4 Hz. various input configurations were also tested, where either only optic flow or wind was oscillated (while the other remained constant), both input stimuli were oscillated in phase or counter-phase (i.e. minimal wind when maximum optic flow). 20 flies were tested for each combination of stimuli oscillation frequency and input configuration, while the forward thrust, wing beat frequency and abdomen pitch were measured.

Results obtained showed that the flies are indeed sensitive to both changes in optic flow and wind and produces the largest thrust and pitch response when both were varied in phase. It was also found that the pitch response decays in amplitude and phase, similar to the response of a low pass filter, while the thrust response had insignificant changes in amplitude and phase over different tested frequencies.

TALK **TUESDAY 3.45PM**

POSTER NUMBER **18**

Increase in information processing capacity with approach to criticality in developing neural networks

Joseph Lizier[1], Viola Priesemann[2,3], Michael Wibral[4], Edward T Bullmore[5-7], Ole Paulsen[8], Paul Charlesworth[8], Manuel S Schröter[5]

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Human brains possess sophisticated information processing capabilities, which rely on the coordinated interplay of several billions of neurons. Despite recent advances in characterizing functional brain circuitry, however, it remains a major challenge to understand the principles of how functional neural networks develop and maintain these processing capabilities. Using multi-electrode spike recordings in mouse hippocampal and cortical neurons over the first four weeks in vitro, we demonstrate that developing neuronal networks increase their information processing capacities, as quantified by transfer entropy and active information storage[1,2]. The increase in processing capacity is tightly linked with approaching criticality (correlation $r = 0.68$, $p < 1e\text{-}9$; $r = 0.55$, $p < 1e\text{-}6$ for transfer and storage, respectively). This increase of processing capacity with approaching a critical state has been predicted by modelling studies[1,3,4], and our results are the first to confirm this prediction experimentally. We therefore suggest that neural networks approach a critical state during maturation with the aim to increase their processing capabilities.

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POSTER NUMBER **12**

An analytical model of simple cell receptive fields: the two-dimensional Gabor function adapted to natural image statistics

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Efficient neural coding of visual sensory information most likely requires that simple cells in the primary visual cortex are adapted to the statistics of natural images. Neuroscientists have long understood the electrophysiology of simple cells in terms of the two-dimensional Gabor function. In this work, I adapt the two-dimensional Gabor function to the statistics of natural images by learning the joint distribution of the Gabor function parameters. The parameter joint distribution is then approximated to yield a tractable generative model of simple-cell receptive fields. Learning is found to be most pronounced in three Gabor parameters that represent the size, aspect-ratio, and spatial frequency of the two-dimensional Gabor function. These three parameters are characterized by non-uniform marginal distributions with heavy tails -- most likely due to scale invariance in natural images -- and all three parameters are strongly correlated: resulting in a basis of multiscale Gabor functions with similar aspect-ratios, and size-dependent spatial frequencies. Some Gabor functions are found to include well-resolved orientation tuning, while others include well-resolved spatial frequency tuning. A comparison with estimates for biological simple cells shows that the Gabor function adapted to natural image statistics correctly predicts some key receptive field properties, but not others.

TALK **WEDNESDAY 1.30PM**

Serotonin and the regulation of adaptive behaviour

Zachary F Mainen, Eran Lottem, Sara Matthias, Magor Lorincz

Champalimaud Centre for the Unknown, Lisbon Portugal

Serotonin is a clinically important neuromodulator that has been implicated in the regulation of many behavioural and physiological functions, but which has eluded a coherent conceptualization. Computational theories of serotonin function have emphasized its role in affective behaviour, particularly in responses to negative reinforcement and in conditions in which patience is required. Here I will present results from recent studies using optogenetic approaches in mice that have allowed us to selectively record and stimulate serotonin neurons with high selectivity and temporal precision. We find that serotonin neurons are phasically activated by prediction errors, signalling both positive and negative surprises. We also find that such serotonin transients produce rapid modulation of behaviour that is context-dependent and is neither positively or negatively reinforcing. Furthermore, at the neuronal level, we find that serotonin precisely regulates the balance between spontaneous and sensory-driven activity. Based on these and other data, we suggest a view in which the primary role of serotonin in neural computation is the report of uncertainty and its use for the regulation of internal predictive models that drive adaptive behaviour.

TALK **THURSDAY 9.45AM**

Towards a cellular-resolution connectome of the primate brain

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Fluorescent tracer injection studies provide valuable insight into brain circuitry. However, the classical way of presenting results is not optimal, since these are tied to a particular set of neuroanatomical delineations of areas and nuclei. This makes difficult to compare results of studies from different laboratories, or to reuse data from previous investigations to refine hypotheses. Moreover, data are not typically preserved in three-dimensional space, which hampers spatially based analyses and comparisons with imaging methods. To address these issues, we propose a workflow for mapping marmoset connectivity data obtained from tracer injection studies into a reference template space of a stereotaxic atlas [Paxinos et al, The Marmoset Brain in Stereotaxic Coordinates, Academic Press 2012].

Nine marmosets were injected with retrograde tracers in the dorsolateral prefrontal cortex. Due to the limited number of distinguishable tracers, building a map of connectivity requires the registration of multiple specimens to a common atlas. In the initial stage of the process of mapping data into atlas space, the positions of labelled cells are registered to neighboring Nissl-stained sections. Then, the Nissl sections are stacked and reconstructed into volumetric form. This reconstruction is performed using affine transformations before applying deformable warping to account for section specific distortions into the atlas space [Avants et al, NeuroImage 54: 2033–44]. The procedure yields a set of spatial transformations which are then applied to the actual cell locations. The reconstruction process results in: 1) A 3D brain volume based on series of stained sections and 2) locations of individual cells labelled with fluorescence tracer expressed in the standardized reference coordinates. The results can be visualised either using a 3D model of the marmoset brain or projected onto a cortical flat map.

The reliability of the workflow was assessed by comparing the number of cells in each cortical area, as estimated by the automated approach, with cell counts determined manually by experienced anatomists. Another validation was comparison between the stereotaxic coordinates of the injection sites estimated by the automated procedure, and those determined by experienced anatomists.

Ultimately, the procedure will be employed to map the results of hundreds of injections and to create a map of the full pattern of interconnections between areas of a marmoset cortex. This will allow purely spatially based comparisons of connectivity studies with those obtained with histological, functional or three dimensional imaging methods, retrieval of quantitative information, and different statistical analyses.

The project is supported by the Australian Research Council grant (DP140101968) and an infrastructural grant from the Polish Ministry of Regional Development (POIG.02.03.00-00-003/09)

TALK **WEDNESDAY 12.15PM**

POSTER NUMBER **19**

Low-intensity repetitive transcranial magnetic stimulation modulates visual evoked responses depending on activity during stimulation

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Modulation of brain activity, for example by low-intensity repetitive transcranial stimulation (LI rTMS) has promise for treating neurological and psychiatric disorders. However, clinical studies suggest high variability in outcomes, which may be attributed to individual differences in brain activity. In this study, we recorded visual evoked potentials (VEPs) from anesthetised mice, before and after 10Hz LI rTMS or sham to examine the interaction between endogenous and induced activity during LI rTMS. We also explored the role of coordinated and random cortical activity by manipulating 1) synchrony in the cortical response: comparing wildtype to ephrin A2A5 / mice, which have disordered visual projections and 2) presence or absence of evoked responses: comparing LI-rTMS applied in the light or dark. Validating our model, before LI rTMS, VEP response peak amplitudes were significantly smaller in ephrin A2A5 / mice than wildtypes, consistent with asynchronous responses from disordered projections. LI rTMS with concurrent visual input significantly decreased peak to peak amplitudes compared to baseline in wildtypes, such that responses were similar to those of ephrin A2A5 / mice. However, LI rTMS applied in the dark decreased amplitude similarly in sham and LI-rTMS groups, with no change in ephrin A2A5 / mice. This decrease was most pronounced in VEP peaks associated with GABAergic inhibition, suggesting LI-rTMS interacts with visually evoked responses and excitation-inhibition balance, which may be permissive for long-term plasticity. This is the first evidence that degree of coordinated and random neural activity during stimulation affects LI rTMS response, and has implications for clinical utility of LI-rTMS as an adjuvant therapy, such as in rehabilitation therapy following stroke.

TALK **WEDNESDAY 2.15PM**

Hippocampal prefrontal circuits that mediate fear learning and extinction

Roger Marek, Helen Gooch, Cornelia Strobel, Pankaj Sah

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Fear conditioning is a Pavlovian Learning paradigm in which in which a neutral stimulus, the conditioned stimulus (CS), such as a light or tone, is temporally paired with an aversive stimulus, the unconditioned stimulus (US), typically a footshock. Following a small number of pairings, subjects form an association between the CS and US, and learn to respond to the CS with an avoidance response, the conditioned response (CR), which is rapidly acquired and long lasting. Subsequent presentations of the CS that are not paired with the US break this association, and lead to a gradual reduction of the CR through a process known as extinction. Studies have clearly established that the three key structures, the amygdala, medial prefrontal cortex (mPFC) and the hippocampus play a central role in fear learning and extinction. However the neural connections between these that mediate this learning are just beginning to be elucidated. In this talk, using acute slice recordings coupled with optogenetic stimulation, I will describe some of the cell types, and neural connections within and between the amygdala and mPFC, and between the hippocampus and mPFC that mediate fear learning and extinction.

POSTER NUMBER **41**

High resolution imaging of cortical structures in the human visual cortex using ultra-high-field fMRI

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The University of Queensland

Neurones in the mammalian visual cortex that respond to the same input feature are arranged in columns. Examples of these columns are ocular dominance (OD), where neurones prefer input from one eye to the other, and orientation preference (OP), where neurones are more receptive to bars oriented at specific directions. This study aims to develop improved experimental paradigms, image acquisition protocols, and processing pipelines in functional magnetic resonance imaging (fMRI) to reliably map OD and OP columns in the human brain.

Animal models have shown that conditions such as monocular deprivation and stripe rearing could alter the characteristics of and relationship between feature maps. These results can be of great importance in understanding how the brain develops. However, we currently lack such information in humans.

To image the same features in the human primary visual cortex (V1) in vivo and at high resolution, we used fMRI at ultra-high field strength of 7 Tesla. We have acquired full brain coverage at isotropic resolution of 0.75mm for the anatomical scans. These high-resolution images were processed to generate computationally flattened cortical sheets. For the functional scans, we have obtained partial brain coverage with oblique slices parallel to the calcarine sulcus at isotropic imaging resolution of 0.8mm. We used a 2D GE-EPI sequence with TR/TE=3000ms/28.6ms. Results presented here include functional activation from retinotopic mapping and OP imaging overlaid on flattened images of the visual cortex.

TALK **WEDNESDAY 11.30AM**

Neural correlates of selective visual attention for interactive approach and avoidance

Jason B Mattingley, Angela I Renton, David R Painter

The University of Queensland, Australia

Mechanisms of visual attention allow us to process behaviourally relevant stimuli while filtering out irrelevant distractions. Despite an extensive literature on the cognitive and neural processes responsible for selective attention, little is known about how people attend when competing stimuli must be approached or avoided, as occurs in many real life situations. Here, electroencephalography (EEG) and frequency tagging were used to measure neural activity while participants manoeuvred a cursor amongst a large set of moving objects. In Experiment 1, participants were rewarded for pursuing objects in one colour and simultaneously "punished" for failing to avoid objects in a different colour, with a third set of coloured objects serving as neutral distractors. In Experiment 2, approach and avoidance were assessed in separate blocks of trials with competing low- and high-priority rewards or deductions. Across both experiments, approached, avoided and neutral objects were tagged at unique flicker frequencies, producing steady-state visual evoked potentials (SSVEPs) that were recovered using frequency-based analyses. In Experiment 1, approached objects elicited larger SSVEP amplitudes than neutral and avoided objects, which produced similar amplitudes. In Experiment 2, SSVEP amplitudes for approached objects scaled positively with priority. High-priority approach produced larger amplitudes than low-priority approach, which in turn produced larger amplitudes than neutral objects. In contrast, SSVEP amplitudes for avoided objects did not scale with priority. Relative to neutral objects, both high- and low-priority avoided objects were similarly suppressed. These findings suggest that attentional modulation for approached and avoided objects occurs via distinct neural mechanisms.

TALK **TUESDAY 5.00PM**

POSTER NUMBER **20**

Can deep-learning algorithms be instantiated in realistic cortical microcircuit models?

Mark D McDonnell

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In computer science, 'deep learning' [1] approaches that aim to model high-level abstractions in data are at last realising the decades-old theoretical potential of artificial neural networks, now to frequently achieve better-than-human performance on difficult pattern recognition tasks.

Deep learning is often characterized as 'biologically inspired' [1]. The basis for this is that the hierarchy of 'layers' of nonlinear processing units in deep neural networks resembles the hierarchical organisation of the mammalian visual cortex, while the use of spatial filters and pooling are reminiscent of the properties of simple and complex cells.

From the neuroscience perspective, these parallels are superficial. An open challenge is to identify whether the spectacular performance of deep neural networks can be replicated in detailed models of cortical neurobiology that are constrained by known anatomical and physiology. Of particular importance in this respect is to identify neurobiologically-plausible learning rules that match the performance of the biologically-unrealistic backpropagation and stochastic gradient descent algorithms used as standard methods when training deep-neural networks.

As a step toward this goal, I present a model of learning in recurrently-connected layer 2/3 and layer 4 cortical neurons. Features of the model include nonlinear dendritic activation, anti-Hebbian plasticity at synapses on distal dendrites receiving lateral input from other principal cells, top-down modulation during learning, and lateral inhibition enforcing winner-take-all effects to determine inference.

Following training with the MNIST handwritten digits image database, the model classifies new test images with less than a 1% error rate. This performance is comparable with state of the art deep-learning algorithms applied to this well-known benchmark.

References:

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POSTER NUMBER **52**

The subcortical route to the amygdala: spatial frequencies and facial expressions

Jessica McFadyen[1,6], Martial Mermillod[2,3], Veronika Halász[1,4], Jason B Mattingley[4,5,6], Marta I Garrido[1,4,6]

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Converging evidence from human and animal studies suggests that there is a colliculo-pulvinar subcortical pathway – the "low road" – that allows low spatial frequency visual information to reach the amygdala, bypassing the visual cortex. While this has been investigated with fMRI in humans, it has not yet been determined whether this route provides a temporal advantage, nor whether such information is conveyed directly to the amygdala without input from higher cortical areas. This study employed dynamic causal modelling (DCM) to investigate whether a subcortical route is engaged in visual processing above and beyond a cortical pathway and, if so, whether a subcortical route is used primarily to transmit salient low spatial frequency information. Neural activity was recorded using magnetoencephalography (MEG) while participants performed a gender discrimination task on neutral or fearful faces presented in broad (BSF), low (LSF), or high (HSF) spatial frequencies. Mass-univariate sensor space analyses revealed a temporal advantage of LSF (85ms) over HSF (175ms) at occipital sensors. Moreover, greater neural signal intensity for LSF faces was associated with faster reaction time. Bayesian model comparison of DCMs demonstrated that neural activity for LSF faces was best modelled by a dual route (i.e. cortical and subcortical amygdala connections). Overall, these initial results support the "low road" hypothesis for conveying visual information directly to the amygdala

TALK **THURSDAY 2.30PM**

POSTER NUMBER **9**

Contrast dependent phase sensitivity of complex cells in primary visual cortex

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Neurons in primary visual cortex are classified as simple if they are sensitive to the phase of drifting sinusoidal gratings presented at their preferred orientation, or complex, if are they are largely insensitive to phase. Here we summarise our recent findings that the phase sensitivity of complex cells increases at low contrast while that of simple cells remains the same at all contrasts. Using oriented gratings that were modulated sinusoidally in both time and space independently, we found that most of the increase in phase sensitivity at low contrasts could be attributed to changes in the spatial phase sensitivities of complex cells. However, at low contrasts the complex cells did not develop the spatiotemporal response characteristics typical of simple cells, in which paired response peaks occur 180° out of phase in both time and space. Complex cells that increased their spatial phase sensitivity at low contrasts were significantly over-represented in the supragranular layers of cortex. We conclude that many complex cells in supragranular layers of cat cortex have spatial summation properties that depend on contrast, and that this aspect of complex cell receptive fields varies across cortical layers.

POSTER NUMBER **35**

Study of basal ganglia subcircuits during the execution of competing actions

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Goal-directed action is amongst the most complex behaviours that both humans and animals can produce. Optimal adaptation to the environment is generally achieved by selecting and executing one action over other possible, less convenient, behaviours, a process that is thought to be mediated by the interplay between the direct and indirect pathways of the basal ganglia. However, the precise way by which these parallel circuits encode the selection of a specific action over other possible behavioural programs (competing action programs) remains to be understood. Here, combining sophisticated instrumental conditioning designs with large-scale neuronal activity mapping in transgenic mice, we studied the activity of large ensembles of spiny projection neurons from the direct (dSPNs) and indirect (iSPNs) pathways in mice that were resolving competing action programs. We found that execution of goal-directed actions triggered the activation of SPNs in the two neuronal systems in vast regions of the posterior dorsal striatum, regardless of whether the executed actions were discrete (one action involved) or mutually exclusive (two competing actions involved). Interestingly, mice resolving competing actions showed higher levels of activity in both dSPNs and iSPNs as compared to mice executing one discrete action, although both behavioural groups showed an equivalent positive correlation between the activities expressed in the two pathways. These results suggest that direct and indirect pathways of the basal ganglia work cooperatively to encode goal-directed action.

POSTER NUMBER **21**

Ion channel noise can explain firing correlation in auditory nerves

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Neural spike trains are commonly characterized as a Poisson point process. However, the Poisson assumption is a poor model for spiking in auditory nerve fibers because it is known that interspike- intervals display positive correlation over long time scales and negative correlation over shorter time scales. We have therefore developed a biophysical model based on the well-known Meddis model of the peripheral auditory system [1], to produce simulated auditory nerve fiber spiking statistics that more closely match the firing correlations observed in the empirical data. We achieve this by introducing biophysically realistic ion channel noise to an inner hair cell membrane potential model that includes (i) fractal fast potassium channels with high conductance and low reversal potential and (ii) deterministic slow potassium channels. We succeed in producing simulated spike train statistics that match empirically observed firing correlations by combining this potassium channel model with a stochastic Markov model for noisy calcium channels and an altered model of the auditory nerve refractory properties. Our model thus replicates macro-scale stochastic spiking statistics in the auditory nerve fibers due to modeling stochasticity at the micro-scale of potassium and calcium ion channels.

References

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POSTER NUMBER **22**

Towards simulation of EMG recording from a hand muscle due to TMS of motor cortex

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Transcranial magnetic stimulation (TMS) manipulates neural activity non-invasively and has shown promising results in treating several neurological disorders such as stroke and depression. Rusu et al. developed a computational model of TMS induced I-waves that reproduced observed epidural recordings in conscious humans [1]. In humans, epidural responses can be recorded in anaesthetized subjects during surgery or conscious subjects with electrodes implanted for the treatment of chronic pain. Such opportunities are uncommon and invasive. The effects of TMS can be non-invasively studied using surface electromyography (EMG) recordings from the hand first dorsal interosseous (FDI) muscle.

We simulate the surface EMG signal due to TMS of motor cortex in the hand FDI muscle during sustained contraction. Our model comprises a population of cortical layer 2/3 cells, which drive layer

5 cortico-motoneuronal cells with excitatory and inhibitory synaptic inputs as in [1]. The layer 5 cells in turn project into a pool of motoneurons, which are modelled as an inhomogeneous population of integrate-and-fire neurons to simulate motor unit recruitment and rate coding. Their input from cortical layer 5 consists of TMS-induced spikes and baseline firing. Hermite-Rodriguez functions are used to simulate motor unit action potential shape. The EMG signal is obtained from the summation of motor unit action potentials of active motor units. Parameters are tuned to simulate recordings from the FDI muscle. Our goal is to determine the biophysical sources of variability in the motor evoked potentials.

References

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POSTER NUMBER **7**

The dorsal visual system predicts future and remembers past eye position

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Eye movements are essential to primate vision but introduce potentially disruptive displacements of the retinal image. To maintain stable vision, the brain is thought to rely on neurons that carry both visual signals and information about the current direction of gaze in their firing rates. We have shown previously that these neurons provide an accurate representation of eye position during fixation, but whether they are updated fast enough during saccadic eye movements to support real-time vision remains controversial. Here we show that not only are these eye-position signals fast and accurate, but also that they carry in parallel a range of time-lagged variants, including predictive and postdictive signals. We recorded extracellular activity in four areas of the macaque dorsal visual cortex during a saccade task, including the lateral and ventral intraparietal areas (LIP, VIP), and the middle temporal (MT) and medial superior temporal (MST) areas. Neurons showed tonic eye-position-related activity during fixation, as well as modulations around the time of saccades, including suppression, enhancement, and pre-saccadic bursts. We show that a hypothetical neuron that pools this population activity through a weighted sum can produce an output that mimics the true spatiotemporal dynamics of the eye. Further, with different pooling weights, the neuron's representation of the eye could be updated well before (<100 ms) or long after (<200 ms) an eye movement. The results suggest a coding scheme in which downstream structures have simultaneous access to past, current, and future eye positions – a basis for spatially invariant representations of visual space.

POSTER NUMBER **44**

The role of the cerebellum in predictive coding during emotional and perceptual processes

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The cerebellum has a well established computational role in motor learning and coordination. The cerebellum employs internal models that represent dynamic properties of movements to generate motor predictions and achieve precise motor control. Considerable interest has recently shifted toward the contribution of the cerebellum to non-motor domains such as cognitive and language processing. However, the mechanisms of that role, particularly in dynamic, ecologically realistic contexts, are not yet established. Here, we examined neural activity in the cerebellum during dynamic perceptual and emotional processes. Functional magnetic resonance imaging data were acquired from 20 healthy control participants whilst they watched a short, emotionally-salient movie. Annotation of the movie and analyses of the imaging data showed that posterior and inferior cerebellar regions were strongly engaged in this dynamic perceptual and affective process with no explicit motor component. Intriguingly, activity of the posterior cerebellar Crus I/II regions tended to peak at surprising moments embedded in the movie. These results suggest that the posterior Crus I/II regions could perform a higher order computation beyond low-level perception, which might be crucial for the comprehension of complex, and dynamic cognitive functions.

POSTER NUMBER **42**

A mathematical model explains saturating axon guidance responses to molecular gradients

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Correct wiring is crucial for the proper functioning of the nervous system. Key signals guiding growth cones, the motile tips of developing axons, to their targets are molecular gradients. However in vitro growth cones trace highly stochastic trajectories, and it is unclear how molecular gradients bias their movement. Here we introduce a mathematical model based on persistence, bias and noise to describe this behaviour, constrained directly by measurements

of the detailed statistics of growth cone movements in both attractive and repulsive gradients in a microfluidic device. This model explains the long-standing mystery that average axon turning angles in gradients in vitro saturate very rapidly with time at relatively small values and emphasizes the importance of adhesion points on growth cone trajectories. This work introduces the most accurate predictive model of growth cone trajectories to date, and deepens our understanding of axon guidance events both in vitro and in vivo.

TALK **WEDNESDAY 4.45PM**

The application of recommendation architecture in managing interference between prior and later learning

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Spiking neural network models have emerged as plausible paradigms for characterizing neural dynamics in the cerebral cortex and for engineering applications. However, such networks also suffer from limited learning capacities mediated by catastrophic interference between later learning and earlier learning. In recent years, there have been numerous attempts to address this issue but success has been limited to the relational complexity and dimensionality of the targeted problem and network size. It is proposed that learning complex combinations of information and avoiding interference in such networks depends on maintaining information fidelity under change, where adequate meanings for information generated by one part of the network can be used for different purposes in many other parts. Towards this end, we investigate the performance of a recommendation architecture based computer model of a cortical area with spiking pyramidal neurons and interneurons organized into layers and columns. Here, the pyramidal neurons are constructed as having complex dendritic trees with multiple branches that are separately integrated, where initial connectivity is determined randomly with some biases and while synaptic weights change by a timing coincidence mechanism. The investigation targets the dependence of learning and discrimination capacity on a range of physiological and anatomical parameters including plausible neural algorithms, number of columns, number of neurons per column, and neuron thresholds. The model demonstrates a capability to heuristically define column receptive fields and discriminate between different categories of input objects, and more importantly, capable of avoiding interference between later and prior learning through limited consequence feedback.

POSTER NUMBER **60**

Honeybee handedness: mathematical modelling of visual lateralisation in flight route choices

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Honeybees (*Apis mellifera*) appear to choose efficient routes while navigating to food sources. Their strategies for doing so remain unexplained. Recent research showed that Budgerigars, when offered a choice between two apertures, generally tend to choose the wider aperture. However, individual birds have personal preferences for the right or the left aperture. Do bees display similar 'handedness'? Here, we explore whether bees show side-biases in choosing between alternate routes, and use a mathematical model to characterise and analyse the bees' route choices. Bees were flown down a tunnel in which they were made to choose between two apertures of varying width upon entering the tunnel, and again when leaving it. The bees' right and left decisions in the inbound and outbound flights were filmed and analysed using various logistic regression models. The results revealed that, although bees tend to prefer the wider aperture, individual bees have personal right or left biases that vary in strength. The population as a whole displayed no bias. This route choice strategy seems to be beneficial as a group of bees with individually varying bias, but zero overall bias, can potentially transit rapidly through an environment that offers different flight routes. Our study is the first to model the rules and visual lateralisation that govern honeybees' route choices. It is the first demonstration that bees display individually varying 'handedness' - a trait previously thought to be reserved for complex organisms.

POSTER NUMBER **48**

Steady-state evoked potentials reveal visual cortical hyper-excitability to peripheral visual field stimulation in macular degeneration patients with visual hallucinations

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Up to 20% of patients with age-related macular degeneration (MD) experience complex visual hallucinations, a condition known as Charles Bonnet Syndrome (CBS). CBS was first described over 250 years ago but has not been satisfactorily explained. To address this, we examined electrophysiological responses to peripheral visual stimulation in CBS patients as well as MD patients without hallucinations and healthy controls. Participants searched for targets while ignoring peripheral checkerboards that flickered at unique frequencies, thus evoking steady-state evoked potentials. CBS patients showed strikingly elevated neural responses to the checkerboards compared with MD patients and controls. These elevated responses were independent of task demands and were localized to extrastriate visual cortex. These results provide the first evidence for anomalous visual responses to peripheral stimulation in CBS. Our findings extend a theory of visual cortical hyper-excitability in CBS by showing that hyper-excitability affects the sighted periphery and does not result from or lead to attentional impairments.

TALK **WEDNESDAY 4.30PM**

POSTER NUMBER **30**

Local dendritic modulation by multi-sensory input

Lucy M Palmer

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In the living animal, sensory systems are generally not stimulated in isolation but are instead activated collectively. In response to multimodal sensory stimulation, the dendrites of pyramidal neurons in the primary somatosensory cortex receive both feedforward input from the thalamus and feedback input from other cortical areas. The influence of this feedback multimodal input on dendritic function is input specific and largely unknown. We investigated dendritic activity in the hindpaw somatosensory cortex during contralateral hindpaw stimulation alone and during activation of additional sensory-evoked feedback input. Using both single-cell electrophysiology and dendritic 2-photon calcium imaging in vivo, we show that sensory input from the stimulation of a second sense, in this case forepaw stimulation, had different effects on the distal and proximal dendrites of layer 2/3 pyramidal neurons. Forepaw stimulation caused a decrease in the Ca2+ activity of tuft dendrites whereas proximal dendrites had an increase in synaptic input. Taken together, this multimodal input onto layer 2/3 pyramidal neurons led to a balancing of sensory information resulting in no change to the evoked firing rate. These results not only illustrate the counterbalancing interaction of multi-sensory input in cortical neurons but it also highlights the complexity of local dendritic activity during sensory processing.

POSTER NUMBER **25**

Reverberating cell assemblies through GABAergic excitation

Madhusoothanan Bhagavathi Perumal, Peter Stratton, Robert Sullivan, Pankaj Sah

Queensland Brain Institute, Brisbane, Australia

Hebb's proposal of reverberating cell assembly is one of the most elegant hypotheses to describe cognitive processes as discrete synchronized neural networks. Many in-vivo field potential studies suggested existence of such cell assemblies but direct evidences at single neuronal level is limited. It is not know what subset of neurons makes up a cell assembly. The temporal dynamics and synaptic mechanisms are not known. We identified a specific subset of GABA neurons in the mouse amygdala could trigger reverberating feedback excitation with high temporal consistency that is abolished by either GABA-A or AMPA antagonists. These GABA neurons make synapses at pyramidal AIS and parvalbumin expressing interneurons, and receive strong synaptic glutamatergic inputs from the local neurons. We suggest a specific subset of GABAergic and glutamatergic neurons form these assemblies in the mouse amygdala. The temporal dynamics and synaptic mechanisms suggest potential role for these reverberations in generation fast network oscillations.

POSTER NUMBER **66**

Measuring the effects of attention to single fingertips in somatosensory cortex using ultra-high field (7T) fMRI

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Background: Attention to sensory information has been shown to modulate the neuronal processing of that information. For example, visuospatial attention acts by modulating responses at retinotopically appropriate regions of visual cortex. Much less, however, is known about the neuronal processing associated with attending to other modalities of sensory information. One reason for this is that visual cortex is relatively large, and therefore easier to access non-invasively in humans using tools such as fMRI. With high-resolution fMRI, however, it is now possible to access smaller cortical areas. Here, we combined a novel experimental design and high-resolution fMRI to measure the effects of attention to tactile stimulation in somatosensory cortex.

Methods: Functional data were acquired on a MAGNETOM 7T scanner using a 3D-EPI sequence with 0.8mm isotropic resolution. Tactile stimulation was delivered via a piezoelectric vibrotactile stimulator. There were two main experimental conditions: sensory and attention. During the sensory condition, four fingertips on the right hand were stimulated sequentially using a phase-encoded design to localize and map the somatotopic organization of the fingertip representations. During the attention condition, attention was swept across the fingertips in a phase-encoded manner under constant sensory stimulation of all four fingertips.

Results: The attention condition elicited phase-encoded responses along the postcentral gyrus demonstrating that the experimental design permits measurement of attention-related modulation. Moreover, these responses overlapped with those elicited by the sensory condition indicating that attention modulates somatosensory cortex in a somatotopically appropriate fashion.

Conclusion: High-resolution fMRI enables detailed measurements of attentional modulation in somatosensory cortex.

POSTER NUMBER **2**

The neuronal and perceptual effects of visual masking

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The perception and neural representation of a stimulus are influenced by other stimuli that occur nearby in space or time. Visual masking describes the reduction in visibility of a target stimulus by a preceding (forward masking) or succeeding (backward masking) stimulus. Masking illustrates the disconnection between the actual physical stimulus represented by the brain, and what is eventually perceived. To understand the neural correlates of masking, we examined how visual masks affect orientation discrimination in awake rodents, and separately examined neuronal responses to similar stimuli in the primary visual cortex (V1).

Long-Evans rats (n=6) were trained to discriminate the orientation of a Gabor patch presented for 42 ms . These target stimuli were presented at stimulus onset asynchronies (SOA) of –250 to 250 ms relative to an uninformative mask. In anaesthetised animals (n=28) neuronal responses to target and mask stimuli were recorded from all layers of V1 using a 32-channel linear array.

Behaviourally, for both forward and backward masking conditions, discrimination performance was impaired when target and mask occurred close in time (i.e. short SOAs). Similarly, across all neural layers neuronal orientation selectivity decreased monotonically with shorter SOAs particularly in forward masking conditions. SOA did not significantly affect neuronal response latency or the time until orientation selectivity emerged.

Behavioural and neuronal orientation discrimination is impeded at short SOAs, with the strongest effects occurring in forward masking conditions. Collectively, our data suggests that reductions in V1 activity are responsible for the reduced perceptual discrimination during masking.

TALK **THURSDAY 11.15AM**

Wiring the brain for function

Linda J Richards

The University of Queensland, Queensland Brain Institute and School of Biomedical Sciences, Brisbane, Australia

The correct wiring of the brain is essential for function. My laboratory investigates the important genetic, molecular and cellular mechanisms regulating the development of brain wiring and how changes in brain wiring affect brain function throughout life. We study the largest connection in the brain, called the corpus callosum, which connects the two cerebral hemispheres. The mechanisms regulating the formation of the corpus callosum are complex, as they involve all of the developmental mechanisms required to form a functioning brain, and thus disruption of these mechanisms may lead to major disruptions in brain wiring and formation of the corpus callosum. In addition to investigating the mechanisms involved in the formation of the corpus callosum, we are also striving to understand how other seemingly unrelated structural brain malformations that co-occur with callosal dysgenesis, could be due to the disruption of similar cellular and molecular mechanisms. Subjects with corpus callosum agenesis/dysgenesis are currently identified based on their structural midline phenotype, a limit imposed by current clinical neuroimaging capabilities. However, these subjects are likely to represent sub-groups with more severe forms of callosal dysgenesis. More subtle changes in callosal targeting could represent a much larger and diverse group of subjects that have normal midline crossing, but disrupted targeting in the contralateral hemisphere. This area of research is in its formative stages but could offer potentially major breakthroughs in how the brain is normally wired during development and what mechanisms may be disrupted in disorders of brain connectivity.

Acknowledgement of funding: Our research is funded by project grants from the National Health and Medical Research Council, Australia, the Australian Research Council, and the National Institutes of Health, USA. LJR is supported by an NHMRC Principal Research Fellowship.

POSTER NUMBER **45**

Metastable wave patterns on the human connectome

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Systems Neuroscience Group, QIMR Berghofer Medical Research Institute

Advances in mapping the human connectome have yielded increasingly-detailed descriptions of large-scale brain networks, prompting growing interest in the dynamics that emerge from this structural connectivity. Moreover, there is a desire to move beyond simple static functional connectivity measures to better describe and understand the more complex repertoire of brain dynamics, which unfolds on multiple time scales. Here, we analyze the dynamics that emerge from a neural mass model with network connectivity derived from densely-seeded probabilistic tractography. We find a rich array of three-dimensional wave patterns, including traveling waves, scroll waves, and breathers. These patterns are metastable, with the dynamics cycling between several relatively long-lived states. These dynamics accord with empirical data from multiple imaging modalities, including observations of electrical waves in cortical tissue and the presence of sequential spatiotemporal patterns in resting state functional neuroimaging (rs-fMRI) data. By characterizing the dynamic states and time scales in our simulated data, we lay a platform for more detailed analyses of large-scale functional neuroimaging data and their mechanistic underpinnings.

TALK **WEDNESDAY 9.45AM**

Physiology-based quantitative modeling and analysis of brain activity and structure underlying attention, prediction, and decision

Peter A Robinson

School of Physics, University of Sydney
Centre for Integrative Brain Function, University of Sydney

Much progress has been made in modeling and analysis of brain activity and structure, starting from physiology. This enables activity to be predicted and analyzed in terms of underlying structure, and vice versa, across scales from single neurons to the whole brain. Key results on structure and activity, and their experimental tests, will be illustrated before discussing some current issues relating to how data-fusion concepts for attention, prediction, and decision can be realized and tested in actual brains.

POSTER NUMBER **6**

Feature selectivity of neurons in the dorsomedial (DM) area of the marmoset visual cortex

Declan Rowley, Saman Haghgooie, Elizabeth Zavitz, Nicholas Price, Marcello Rosa, Hsin-Hao Yu

Department of Physiology, Monash University

The dorsomedial (DM) area in the visual cortex of the New World marmoset monkey is considered an intermediate-level area in the hierarchy of cortical visual processing, because it receives most of its input from lower-level areas such as V1, V2, and MT. It has been proposed to be homologous to area V6 in the macaque. In anaesthetised marmosets, we examine DM neurons' selectivity to visual features with white noise analysis (i.e., reverse correlation). Checkerboard patterns with squares randomly drawn from three levels of brightness (bright, grey, dark) were rapidly (60 Hz) presented monocularly to the animal. A 96-channel Utah array, which covered the entire width of dorsal DM and small parts of area V2 and DA, recorded single-unit activities in the infragranular layers of the cortex. Spike-triggered covariance (STC) analysis indicated that the responses of almost all the recorded DM neurons could be characterised by oriented filters resembling Gabor functions. Similar to complex cells in V1, the linear subspaces of spike-triggering patterns were spanned by quadrature-pair filters, producing invariant responses to the spatial phase of sinusoidal patterns. No direction selectivity was observed. The temporal window of information integration in DM was approximately from 32 to 80 ms prior to spikes. We have reported a successful application of white noise analysis in an extrastriate area in the primate visual cortex. The classical receptive fields of DM were surprisingly similar to what has been observed in V1, highlighting DM's functional role in orientation processing.

POSTER NUMBER **58**

Using context adaptive deep neural networks for emulating human auditory cortex

Nikodem Rybak

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Recognition of complex emotional states, expressed by voice, is a unique human quality. The human brain is capable of decoding variable acoustic inputs into meaningful patterns.

Research findings show that the early auditory system decomposes speech and other complex sounds into elementary time-frequency representations. However, there is a limited understanding of acoustic features and mechanisms involved in the natural speech processing done by the intermediate and higher order human auditory cortex. Revealing these decoding mechanisms by invasive recording of cortical activity is infeasible.

This study explores adoption of the theory of Deep Neural Networks (DNNs) for acoustic modelling to emulate the brain learning procedures by executing DNNs in massive parallel neuron-like hardware. Early findings led to a novel approach of using context adaptive DNNs with parameters directly dependent on factors characterized by the acoustic context. This approach enables representation of the long-term acoustic context for recognition of emotional states expressed by voice.

This study contributes to the field of computational neuroscience by assisting with verifying voice processing hypotheses.

POSTER NUMBER **61**

Visual control of flight speed in budgerigars

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One intriguing questions about animal flight concerns whether, and to what extent, vision is used to adjust the speed at which animals move in their environment. Insects continuously adjust their speed to suit the environment: the more cluttered it is, the slower the flight.

Here we examine the behaviour of budgerigars as they fly through a progressively narrowing tunnel. In the first section of the tunnel the birds fly at a high speed of ~ 10 m/s, which closely matches their energy-optimal flight speed. At a certain point in the tunnel speed drops abruptly to a lower level (~ 5 m/s) and stays low for the rest of the flight. When the birds fly through a progressively widening tunnel, they commence their flight at the lower speed, and then switch to the higher speed.

Our findings suggest that the birds fly at the high, energy-efficient speed whenever the tunnel is wide enough to permit safe flight, and switch to the lower speed when the tunnel becomes narrower than a critical value. Analysis reveals that the birds switch between the two speeds in an anticipatory fashion by evaluating the oncoming environment at a viewing angle of about 20 deg.

Unlike flying insects, which display a continuum of flight speeds, budgerigars appear to use a twin-speed flight system. The advantage of a system that incorporates only two 'known' speeds is that, for each speed, the distances to oncoming obstacles can be directly calibrated in terms of the optic flow that they elicit.

POSTER NUMBER **23**

A model for learning in the piriform cortex using two types of principle cells

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In studies of sensory processing the olfactory system is highlighted as having significant advantages due to the structure of the system. The piriform cortex is the primary cortical area in the olfactory system of mammals and is a 3 layer paleo-cortex that remains remarkably consistent in structure across species. In addition to this the piriform cortex is only two synapses removed from the sensory periphery and its input is not relayed through the thalamus, making it a unique window into cortical information processing.

Recent experimental work has highlighted that there are two types of principal neurons in layer two of the piriform cortex and that their physiology suggests that they play quite different roles in the information processing that occurs. Despite this, functional hypothesizes and computational models of the piriform cortex are notably lacking this detail.

A spiking neural network model of the coupled Olfactory Bulb and piriform cortex that is capable of performing pattern recognition is presented. The learning mechanism that this model uses is inspired in part by the model of the hippocampus, which shares certain structural parallels to the piriform cortex, presented in [2]. Experimental data from [1] and associated publications were used for structure and parameters of the model. This model suggests different possible functional roles of these two types of principal neurons in the piriform cortex. The mechanism for learning uses a combination of short term facilitation and STDP shown to be present in the piriform cortex.

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TALK **WEDNESDAY 12.00PM**

POSTER NUMBER **54**

Contribution of posterior middle temporal gyrus in semantic control

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Semantic cognition involves two interacting components: semantic representation and semantic control. Based on previous findings from semantic representation deficits in semantic dementia (SD) patients and semantic control deficits in stroke aphasia (SA) patients, we used TMS in healthy human volunteers to create "virtual lesions" in structures typically damaged in SD patients: anterior temporal lobes (ATL) and SA patients : left posterior middle temporal gyrus (pMTG) and ventral angular gyrus (vAG). The influence of TMS on tasks varying in semantic representational demands, semantic control demands and tasks involving non-semantic/visual control demands was examined for each region. Preliminary results (n=15) revealed pMTG supports both the controlled retrieval and selection of semantic knowledge. The pattern of results obtained for pMTG, combined with previous evidence about it, are consistent with a large-scale semantic control network, as supported by lesion data in SA involving left inferior frontal gyrus (LIFG) and pMTG and angular gyrus (AG).

POSTER NUMBER **10**

Irregularly timed biphasic pulses increase efficacy of retinal ganglion cell responses

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The phenomenon of image fading is characterised by the inability to perceive an image via a visual prosthesis when an electrical stimulus does not change temporally. Such a phe- nomenon is believed to be caused by neural adaptation in the visual cortex and in the retina. In this work, we propose to limit the adaptation in the retina by stimulating retinal ganglion cells (RGCs) with biphasic pulses that are distributed in time according to a Poisson process.

RGCs (n=28) were stimulated with an epiretinal platinum electrode by delivering trains of biphasic pulses at a rate of 10, 50 and 200 pulses per second. Two stimulation protocols were used. Protocol 1 had variable inter-pulse intervals (IPIs) distributed in time according to a Poisson process. Protocol 2 had constant IPIs. Protocols 1 and 2, and stimulation frequency were randomly intercalated when stimulating a cell.

RGCs showed adaptation to both types of stimulation protocols. However, the response of the cells decayed faster when stimulating with constant IPI pulses at 50 and 200 Hz, com- pared to Poisson distributed IPI pulses. Furthermore, the spike rate was significantly higher when stimulating with Protocol 1. No significant difference in the spike rate was observed between the two protocols when stimulating at 10 Hz. Nevertheless, the cells showed faster adaptation to Poisson distributed IPI pulse stimulation than to constant IPI pulse stimula- tion at this frequency.

Our results indicate that using stimulation with Poisson distributed IPI pulses may limit adaptation and lead to better efficacy of currently used retinal prostheses.

TALK **THURSDAY 11.15AM**

Vision and navigation in bees and birds and applications to flying machines

Mandyam V Srinivasan

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Flying insects are remarkably adept at seeing and perceiving the world and navigating effectively in it, despite possessing a brain that weighs less than a milligram. This presentation will describe our recent progress in understanding how honeybees use their vision to control and regulate their flight speed, negotiate narrow passages, avoid mid-air collisions and perform smooth landings, using computational principles that are often elegant and unprecedented. It will also outline our investigations of visually guided flight in birds, and conclude with an update of our advances in the design and testing of biologically inspired vision systems for autonomous aerial vehicles.

POSTER NUMBER **26**

Flexible neural correlations for information processing: experimental and modelling results

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Changes in neuron spiking rates and spiking phase with respect to local field potential oscillations are well known. What is sometimes not so widely appreciated is that correlations between spikes from different neurons also change over short timescales. These changes are in response to not just sensory stimuli, but also occur spontaneously (in rats) and in response to mental tasks (in humans). I will present analyses of some of the tetrode recordings we have obtained from the amygdala of rats during rest and fear conditioning, and during surgery for electrode implantation for deep brain stimulation in people. These observations have led to a spike-level model of neural activity. The model uses intrinsic noise and random, but fixed, spike conduction delays to generate oscillations and changing spike correlations. I will speculate how spike timing and conduction delays could potentially be used to implement flexible neural information processing.

POSTER NUMBER **53**

An electroencephalographic pattern recognition-based diagnosis of schizophrenia

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University of Queensland

Schizophrenia is typically diagnosed through symptomatic evidence collected through patient interview. We hope to devise a biologically-based computational tool which aids diagnosis and relies on accessible imaging technologies such as Electroencephalography (EEG). Mismatch negativity (MMN) is an EEG component elicited by unpredictable changes in sequences of auditory stimuli [1]. MMN is reduced in people with schizophrenia and this is arguably its most reproducible neurophysiological marker [2,3]. We recorded EEG data from 21 schizophrenia patients and 22 healthy controls whilst they listened to tones that changed occasionally (10% of trials were deviant tones). Three specific deviant tone types that were all equal to standard tones, except for one physical aspect: 1) duration - the deviant stimulus was twice the duration of the standard; 2) gap – standards were white noise bursts and deviants had a muted interval within this burst, and 3) interaural time difference - deviants were perceived as 90° away from the standards. We used multivariate machine learning techniques implemented in the Pattern Recognition for Neuroimaging Toolbox [4] (PRoNTo), originally designed for classification of fMRI datasets. These methods were adapted for images generated through statistical parametric mapping (SPM) of the spatiotemporal images of EEG, i.e. event-related potentials measured on the two-dimensional surface of the scalp over time [5]. Using support vector machine and Gaussian processes, we were able classify patients and controls with total accuracies of up to 80.49% (p-values <0.001). Crucially, some of these models are highly robust across multiple cross- validation schema.

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TALK **THURSDAY 12.30PM**

POSTER NUMBER **63**

Understanding insect habituation and recalibration: learning in a dynamic virtual reality environment

Matthew N Van De Poll[1], James O Steeves[1], Esmi L Zajaczkowski[1], Gavin J Taylor[1,2], Bruno van Swinderen[1]

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In nature, animals that fail to learn are often subject to a quick end. In the laboratory, understanding the depth to which an animal can learn and how quickly it adjusts to a novel situation provides valuable insights into potential mechanisms driving behavior. Our work used a computer-generated wrap-around visual environment to probe honeybee (*Apis mellifera*) and fruit-fly (*Drosophila melanogaster*) learning and habituation. To avoid the typical constraints of other tethered visual behavioural paradigms, a dynamic virtual topography underpinned presentation and motion of stimuli in our paradigm. For both honeybees and *Drosophila*, adaptation to the unnatural tethered virtual reality environment was surprisingly fast and there was a robust improvement in proficiency over time. A competition scenario using green bars flickering at different rates (2–100 Hz) revealed that honeybees significantly preferred middle-range frequencies (20–25 Hz) but showed aversion to low and high frequencies (2–4 Hz, 50–100 Hz). Interestingly, attention-like behaviour changed over time with animals appearing to habituate towards low (2–4 Hz) and middle (20–25 Hz) frequencies. However, high frequencies (50–100Hz) remained aversive throughout. Temporal recalibration experiments in *Drosophila*, using single bars equipped with a sensory feedback delay, showed that effective feedback-delay compensation was possible up to ~90ms. Furthermore, a high delay of 150ms preceding exposure to smaller delays facilitated enhanced recalibration performance. Overall, we have shown that insect learning and habituation can be assessed in a virtual setting. Our dynamic visual stimuli paradigm provides a novel way to study multiple combinations of stimuli simultaneously.

POSTER NUMBER **36**

Auditory response in the zebrafish brain

Vanwalleghem G, Schuster K, Scott EK

QBI, SBMS, The University of Queensland

As a transparent animal and with the rise of powerful light-based tools to monitor and manipulate the brain, the larval zebrafish offers a perfect window into functioning neural circuits. The system is particularly promising given the similarities that exist in the key sensory processing centres between zebrafish and mammals.

We are using the genetically encoded calcium sensor GCaMP6 and single plane illumination microscopy (SPIM), we are mapping out the auditory response in the zebrafish brain. For the data analysis, we are using the Thunder library running on the NECTAR cluster. For feature extraction we use simple correlation and non-negative matrix factorization combined with fast nonnegative deconvolution for spike train inference. This allows us to study circuit dynamics with good temporal resolution and single neuron spatial resolution.

We first assayed the range of hearing of the larval zebrafish to different frequencies. The zebrafish is able to hear between 100 and 500 Hz, but higher frequencies do not appear to elicit any neural response in the brain. The neurons appear broadly tuned to the various frequencies and neomycin treatment did not disrupt the neural responses, showing they are indeed auditory and not from the lateral line. Auditory responses were observed as expected in the torus semicircularis, but also in an as yet unidentified dorsal region of the hindbrain. Future work will investigate the direction selectivity and volume sensitivity of those neurons.

POSTER NUMBER **62**

Anticipatory flight planning in birds

Hong Vo, Ingo Schiffner, Mandyam Srinivasan

Queensland Brain Institute, The University of Queensland, Australia

It is essential for birds to be agile and aware of their immediate environment, especially when flying through dense foliage. To investigate the type of visual signals and strategies used by birds while negotiating cluttered environments, we presented budgerigars with vertically oriented apertures of different widths. We find that, when flying through narrow apertures, birds execute their maneuvers in an anticipatory fashion, with wing closures, if necessary, occurring well in advance of the aperture. When passing through an aperture that is narrower than the wingspan, the birds close their wings at a specific, constant distance before the aperture, which is independent of aperture width. In these cases, the birds also fly significantly higher, possibly pre- compensating for the drop in altitude. The speed of approach is largely constant, and independent of the width of the aperture. The constancy of the approach speed suggests a simple means by which optic flow can be used to gauge the distance and width of the aperture, and guide wing closure.

POSTER NUMBER **59**

Real time million-neuron simulation of balanced neural networks

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We present a high performance system called DeepSouth for simulating large-scale spiking neural networks. DeepSouth is capable of simulating up to 10 billion leaky- integrate-and-fire (LIF) neurons (each could have more than 13.5k synaptic connections) in real time. DeepSouth is a free, open-source, parallelisable and scalable simulator, designed to run on Field Programmable Gate Arrays (FPGAs). It can be easily re-configured for simulating different neural networks without any change to its own hardware structure since all the required neural parameters and connections are stored in on- and off-chip memories. Along with the hardware platform, we also developed an interface that will allow users to specify the parameters of neurons and connections, as well as the network structure using Python and the PyNN API [1]. This will have the advantage that many existing designs formulated in PyNN will be able to be simulated on our FPGA platform directly. We demonstrate the capability of the DeepSouth by building a balanced spiking neural network [2] with 1 million LIF neurons, which exhibits dynamics of excitation and inhabitation. DeepSouth will be of use to both the computational neuroscience and neuromorphic engineering communities, providing an affordable and scalable tool for design, real-time simulation, and analysis of large-scale spiking neural networks.

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TALK **WEDNESDAY 4.00PM**

Active dendritic integration underlies circuit-based computations in the neocortex and retina

Stephen R Williams

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Neuronal circuits have been subject to detailed anatomical and functional investigation for over a century, yet our understanding of how circuit-based computations are executed remains in its infancy. The development of functional recording techniques, which enable the direct examination of physiologically engaged neuronal circuit operations are, however, beginning to allow the mechanistic dissection of the rules underlying information processing by neuronal circuitry. Using electrophysiological and imaging techniques we have identified that single neurons possess powerful information-processing capabilities, exhibiting multiple sites for active dendritic integration that locally compute synaptic input and drive the action potential output. Recently we have directly demonstrated that active dendritic integrative mechanisms underlie physiologically engaged circuit-based neuronal computations in the output neurons of the neocortex and retina. This talk will dissect how such circuit-based computations are implemented and modulated.

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POSTER NUMBER **27**

Auditory tone representation in amygdala of naïve animals

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Auditory fear conditioning is a widely used paradigm to study the physiology of associative memory. Based on this model the co-activation of aversive and sensory inputs converging onto neurons of the lateral amygdala is proposed to induce synaptic plasticity that supports fear learning. However, amygdala neurons' activity entrained by auditory stimulation before acquisition of conditioning has not been explored. In this study, male Sprague-Dawley rats (n=5) were implanted with 6 tetrodes targeting the lateral amygdala. During a screening period, started a week after surgery, animals were presented multiple trains of tones (pips: 500ms on ; gaps: 1000ms interval off) at different frequencies (3 to 12 KHz and white noise). We analyzed responses of single units to tones (n= 432) and found that 48% of units were tone-responsive (n=209) and each of these units was responding to 2-3 frequencies. In the range tested, each frequency evoked a response from 20 to 30% of the units while white noise only evoked a response in 15% of the units. Unit activity was studied independently in 3 phases, 41% of units responded during early activation 33% (0-100ms) during late inhibition (100-500ms) and 28% after tone. We used pairwise correlation to study network dynamics in groups of units recorded concurrently in lateral amygdala in this different phase of responses dynamic. Significant interactions were identified, independently of firing rate, based on increased correlation between spike trains. Steady-state visual evoked potentials reveal a neural correlate of visual filling-in in the human visual system

POSTER NUMBER **49**

Steady-state visual evoked potentials reveal a neural correlate of visual filling-in in the human visual system

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Under natural viewing conditions, visual stimuli are often obscured by occluding surfaces. To aid object recognition, the visual system actively reconstructs the missing information, as exemplified in the classic Kanizsa illusion, a phenomenon termed "modal completion". Single-cell recordings in monkeys have shown that neurons in early visual cortex respond to illusory contours, but it has proven difficult to measure the neural correlates of modal completion in humans. Here we used electroencephalography (EEG) to measure steady-state-visual-evoked potentials (SSVEPs) from 'pacman'-shaped disks arranged to induce an illusory shape (or rotated to veto the illusory shape in control trials). Diagonally opposing pairs of disks within the shape configuration were tagged with one of two flicker frequencies (5 or 8 Hz). During stimulus presentations, participants judged the orientation of a briefly flashed bar at fixation, while ignoring congruent (same orientation) or incongruent (different orientation) flanker bars that appeared on or off the illusory surface. Frequency-based analyses revealed that SSVEP amplitudes were reliably enhanced for trials in which an illusory shape appeared, relative to control trials, both at the fundamental flicker frequencies (5 and 8 Hz) and at an intermodulation frequency of 13 Hz. Participants' reaction times in the flanker task were significantly slower for incongruent versus congruent trials, and this effect was larger when an illusory surface was present than when there was no illusory surface. Our results reveal a robust neural correlate of modal completion in the human visual system, and demonstrate the influence of filling-in processes on visual attention.

POSTER NUMBER **11**

Frequency dependence of local field potential responses to electrical stimulation of the retina

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Different frequency bands of the local field potential (LFP) has been shown to reflect neuronal activity occurring at varying cortical scales. As such, recordings of the LFP may offer a novel way to test the efficacy of stimulation strategies for neural prosthetics via neural feedback. We present experimental testing data for a retinal prosthesis, where LFP measurements were used to characterize neural responses to electrical stimulation of the retina. We show that the LFP is a viable signal that contains sufficient information to optimize stimulating neural prostheses. Clinically-relevant electrode arrays were implanted in the suprachoroidal space of the eye, and each electrode was stimulated in a sequential randomized fashion in felines. The LFP was simultaneously recorded through penetrating microelectrode arrays from the primary visual cortex. The frequency response of each electrode was extracted using multi-taper spectral analysis and the uniqueness of the responses was determined via a linear decoder. We find that the LFP is reliably modulated by electrical stimulation of the retina and that responses are spatially localized. We further characterize the frequency dependence of responses of the neural activity, with maximum information being contained in the low and high gamma bands. Finally, we find that LFP responses are unique to a large range of stimulus parameters (~40) with a maximum information rate conveyed of 6.4 bits. These results show that the LFP can be used to validate responses to stimulation of the retina and provide the first steps towards using these responses to provide more efficacious stimulation patterns.

TALK **THURSDAY 2.45PM**

POSTER NUMBER **3**

Rapid adaptation shapes population activity in middle temporal area consistent with perceptual biases

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Each visual experience changes the neural responses to subsequent stimuli. If the brain is unable to incorporate these encoding changes, then decoding, or perception, of subsequent stimuli will be biased. To understand how these biases arise and persist, we examined the responses of a population of motion-sensitive neurons in marmoset middle temporal area (MT) to a continually changing motion stimulus. Patterns of sensory response adaptation continuously evolved across the neural population, with 0.5 second stimuli producing gain changes lasting up to 2 seconds. Decoding individual trials of adaptation-affected activity in 20 simultaneously recorded neurons predicts systematic repulsive perceptual biases consistent with the perceptual direction aftereffect in humans. This neural and perceptual repulsion is likely to be a necessary consequence of optimizing neural encoding for identification of a wide range of stimulus properties. Collectively, our results support theories that short-term sensory adaptation primarily meets the brain's need for homeostasis in neural responses, rather than an attempt to optimize perceptual read-out.

TALK **THURSDAY 1.45PM**

Looking before seeing: exogenous attentional guidance by the primary visual cortex and its interaction with higher level visual functions

Li Zhaoping

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In a field of green leaves, a singleton red flower is highly salient to attract our attention and gaze. Looking at this flower may seem to follow our first seeing it in our peripheral visual field, consistent with traditional ideas that visual attention is guided by frontal and parietal brain areas downstream along the visual pathway from visual cortical areas for object recognition.

However, according to a recent theory, the primary visual cortex (V1), upstream from these visual areas for object recognition, creates a bottom-up saliency map to guide attention exogenously (by direct visual inputs rather than ongoing cognitive goals). Accordingly, shifting gaze exogenously to look at a location can occur before or without seeing or recognizing any object at that location.

This prediction was confirmed: in an image of many items, one item uniquely shown to one eye among the other items shown to the other eye attracted gaze as strongly as the singleton red flower in a green field, even though observers were barely able to see the uniqueness of the attractive item. Furthermore, V1 predicted attentional shifts can fully (quantitatively without free parameters) account for additional behavioral data on singleton visual searches, suggesting that cortical areas downstream from V1 play little role in exogenous attentional guidance.

Finally, I will show some seemingly paradoxical phenomena when the initial looking and the subsequent seeing are pitted against each other in some visual tasks, which help to reveal brain areas involved in seeing.

POSTER NUMBER **55**

Complex network analysis based on single channel sleep EEGs in healthy individuals

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Spatial complex network from multi-channel EEG relations has revealed a higher clustering coefficient topology during wake and sleep, while complex networks from single channel sleep EEG time series are poorly understood. This study investigates significant changes in network topology from wakeful to deep sleep within two public sleep EEG databases. The mean degree (D), local clustering coefficient (C), and mean path (L) are extracted from five EEG channels of 28 healthy subjects. The statistics show that the complex brain networks in deep sleep are characterized by a higher mean degree and lower clustering coefficient, while these values changed on occipital region are more efficient than those on frontal area.

Notes