Student Research Projects 2019-2020

PSY6431

Project Choice Booklet

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MSc Cognitive Neuroscience and Human Neuroimaging Projects

Project Number: 101

Title: BYOM - Bring Your Own Model!

Supervisor/s: Hannes Saal, Stuart Wilson, Robert Schmidt

Location: Cathedral Court / Pam Liversidge Building

Outline: You already have an exciting idea for a computational model that you would like to investigate for your dissertation project? Is that idea more specific than just e.g. ‘modelling memory’ or ‘modelling the basal ganglia’? If so, then we are happy to discuss your idea in more detail to see whether it can be turned into a dissertation project. We would expect that you present your model idea in a 1-page written summary, and explain how you will use the model to answer a specific research question. Ideally, your model should be based on a published model in the scientific literature and you should be able to implement it with your current programming skills. The topic should address a current research area of computational neuroscience.

Suitability: Programming and modelling skills (e.g. based on PSY6307 and PSY6309)

Key references: N/A

Project Number: 102

Title: Big data on learning

Supervisor/s: Tom Stafford

Location: Flexible

Outline: I (Tom) have access to large existing data sets which contain the potential to show skill development on real-world tasks for large numbers of people (i.e. n>1,000,000 in domains of chess and online video games). Using theory from the cognitive science of learning and advanced statistical models and/or data visualisation techniques we will test theories of what makes learning most effective. Can we look at how people practice and relate this to the level of skill they reach? The ambition will be to design more effective learning practices. You will have an opportunity to work with the theory of the psychology of learning and a skill set encompassing state-of-the-art open-source analytics tools.

Suitability: Knowledge of R or Python or a strong willingness to learn these

Key references:
Stafford, T. & Haasnoot, E. (2017). Testing sleep consolidation in skill learning: a field study using an online game. Topics in Cognitive Science. 9(2), 485-496.

Project Number: 103

Title: Microsaccades and ADHD/ASD

Supervisor/s: Tom Stafford

Location: Mushroom Lane & Cathedral Court

Outline: Attention Deficit Hyperactivity Disorder (ADHD) is the most prevalent neurodevelopmental disorder, however the neural changes that underlie the disorder are poorly understood. Recent evidence suggests that a midbrain structure, the superior colliculus, is an important dysfunctional locus in the disorder. The superior colliculus plays a central role in the generation of eye movements, amongst them microsaccades (small amplitude saccades made during fixation), and we have recently shown that microsaccade rate positively correlates with ADHD-type symptoms in a non-clinical adult population, suggestive of a 'hyper-active' colliculus (Panagiotidi et al., 2017). The project we envisage will develop testing of whether it is possible to track changes in microsaccade rate over time in individual participants (Hampsey et al, submitted). In particular, we would like to see if response to caffeinated drinks affects microsaccade rate. Caffeine is a dopamine agonist, and dopamine plays an important functional role in both attention and collicular function). If it is possible to measure the time-response function using microsaccades then this is an important proof-of-concept for testing and developing pharmacotherapies in ADHD which are based on the collulicar hypersensitive hypothesis.

Suitability: Technical aptitude (eye-tracking) and experimental design skills required

Key references: Panagiotidi, M., Overton, P.G., Stafford, T. (2017). Increased microsaccade rate in individuals with ADHD traits. Journal of Eye Movement Research. 10,1
Hampsey, E., Overton, P.G., Stafford, T. (submitted). Microsaccade rate as a measure of drug response. https://psyarxiv.com/r6duk

Project Number: 104

Title: Cognitive Mapping versus Associative accounts of spatial learning in Virtual Reality

Supervisor/s: Stuart Wilson

Location: Pam Liversidge (experiments will take place in the VR lab in the Mappin Mining Block)

Outline: Is spatial learning distinct from other forms of learning? According to associative learning theories, when we encounter new information, whether temporal or spatial, that information is processed according to the same associative mechanisms. In contrast, according to cognitive mapping theory, when we explore a new environment we automatically construct a representation of that environment in which all distinctive landmarks, together with the geometric relationships between those landmarks, are stored. A mental representation of the environment in this structure can be employed to solve novel spatial problems. As such, the mechanisms that underpin spatial learning are presumed to be distinct from those that underpin non-spatial learning Cognitive mapping and associative learning theories make a number of different predictions about the way in which humans and other animals learn about space. For example, associative learning theories predict cue-interaction effects, such as blocking and overshadowing, whereas cognitive mapping theory does not, and cognitive mapping theory predicts that animals can automatically compute novel short-cut routes whereas associative learning does not. The aim of this project is to test the predictions of these two theories, by reproducing experimental designs in either cue-competition or short-cutting that have been well established in the classic animal learning literature, using human participants navigating environments experienced via Virtual Reality. See Alexander, Wilson, Wilson (2009) and Wilson & Wilson (2018 - in press) for examples of studies in this area.

Suitability: This project will involve the design and creation of new Virtual Environments using Unity 3D software. You will recruit participants, collect data in the Sheffield Robotics / INSIGNEO Virtual Reality and Motion Capture Lab in the Mappin Mining Block, and you will perform statistical analyses to test for short-cutting and/or cue-competition. This project is well suited to an experimental psychologist with an interest in computer-aided design or computer gaming. Students with ideas for constructing computational models of spatial learning to explain the existing data are also welcome to apply.

Key references:

O'Keefe J, Nadel L. The hippocampus as a cognitive map. Oxford University Press: Oxford; 1978.

Alexander T, Wilson SP, Wilson PN. (2009) Blocking of spatial learning based on shape. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(3):694–708.

Olton DS. (1978) Mazes, maps, and memory. American Psychologist, 34(7):583–596.

Pearce JM. (2009) The 36th Sir Frederick Bartlett Lecture: An associative analysis of spatial learning. The Quarterly Journal of Experimental Psychology, 62(9):1665–1684.

Wilson SP, Wilson PN (2018) Failure to demonstrate short-cutting in a replication and extension of

Tolman et al.'s spatial learning experiment with humans. PLoS ONE X(Y): e0208794.

Project Number: 105

Title: Telepresence immersion in an animal-like robot

Supervisor/s: Stuart Wilson Tony Prescott (Computer Science and Sheffield Robotics)

Location: Pam Liversidge Building

Outline: We work as part of Sheffield Robotics on biomimetic robotics, with a particular focus on brain-inspired computing, active sensing, scene understanding, episodic and spatial memory, social cognition and human-robot interaction. We are interested in the use of robots as telepresence devices for remote action in work and entertainment settings, and have created various telepresence interfaces for physical robots using virtual reality head-sets and different forms of body tracking (see Martinez-Hernandez et al., 2017). This project would explore whether we can give people a convincing immersive experience in a non-humanoid robot using the MiRo animal-like robot. As well as developing the telepresence system projects could explore its psychological impact. What is the experience of being immersed in a non-humanoid robot? Are there after-effects?

Suitability: Students should have reasonable programming skills (ideally Python or C++) and an interest in societal applications of robotics. Some knowledge of psychology and/or experimental design would be useful. No prior familiarity with robots in needed.

Key references:

Martinez-Hernandez, U., Boorman, L. W. and Prescott, T. J. (2017). Multisensory Wearable Interface for Immersion and Telepresence in Robotics. IEEE Sensors Journal, 17(8), 2534-2541. doi:10.1109/JSEN.2017.2669038

Mitchinson, B. and Prescott, T. J. (2016). MIRO: A Robot Mammal with a Biomimetic Brain-Based Control System. Living Machines V: Biomimetic and Biohybrid Systems, LNCAI 9793, pp. 179-191.

Project Number: 107

Title: Reaction-diffusion modelling of cortical arealization

Supervisor/s: Stuart Wilson and Sebastian James

Location: Pam Liversidge Building

Outline: Morphogenesis (pattern formation) in biological systems can be understood in terms of the tension between local excitatory interactions between cells and longer-ranging inhibitory interactions. Reaction-diffusion models, based on the ideas of Alan Turing, provide a formalism for understanding how this tension can lead to different patterns, e.g., resulting in the stripes versus spots of colour we see on animal skins. Similar processes describe how patterning in the brain occurs, in particular in the developing neocortex. The aim of this project is to investigate how genetic constraints acting on reaction-diffusion processes shape the patterning of the developing neocortex to result in differences in the relative size and shape of the primary cortical areas (A1, V1, S1 etc.). The two papers below by Bard Ermentrout outline a) a reaction-diffusion approach to between-area patterning in a 1D model of cortical development, and b) a reaction-diffusion approach to within-area patterning in a 2D model of cortical development. We have been combining these two approaches to create a reaction-diffusion model with which to investigate between-area pattern formation on a simulated 2D cortical sheet. The aim of this project is to calibrate the model to data obtained by our collaborator lab at University California Davis (Leah Krubitzer), who have been experimentally manipulating the size of the cortical sheet and the sensory experiences of developing animals across a range of mammalian species

Suitability: The mathematics (partial differential equations) and computing (c++ and python) foundations of this project are now fairly well established, and as such projects can be designed around the mathematical/computing expertise and interests of the student.

Key references:

Karbowski, Ermentrout (2004) Model of the Early Development of Thalamo-Cortical Connections and Area Patterning via Signaling Molecules. Journal of Computational Neuroscience 17, 347–363

Ermentrout B, Simons DJ, Land PW (2009) Subbarrel Patterns in Somatosensory Cortical Barrels Can Emerge from Local Dynamic Instabilities. PLoS Computational Biology 5(10): e1000537

Krubitzer, Dooley (2013) Cortical plasticity within and across lifetimes: how can development inform us about phenotypic transformations? Frontiers in Human Neuroscience, 7 (620), 1-14.

Project Number: 108

Title: Artificial gene regulatory networks

Supervisor/s: Stuart Wilson and Daniel Whiteley

Location: Pam Liversidge Building

Outline: We have been using principles from Artificial Neural Networks research to construct models of how gene-regulatory networks evolve and develop. Specifically, we are interested in the networks that give rise to the graded patterns of gene expression that guide development of thalamocortical axons and ultimately specify the primary cortical fields (V1, S1, A1 etc.). In this project we will investigate how constraints on the network architecture (e.g., feed-forward versus fully connected recurrent networks) might account for the range of gene expression patterns observed in real gene networks, using a new technique we have been developing for disabling network learning to represent the effects of gene knock-out experiments. Depending on student interest, there is also scope for exploring these problems further using evolutionary algorithms.

Suitability: The focus of this project can be shifted depending on the expertise/interests of the student either to focus on algorithm development on the reasonably small-scale, or to run more intensive simulations. Willingness to learn c++ and/or python is required.

Key references:

Giacomantonio CE, Goodhill GJ (2010) A Boolean Model of the Gene Regulatory Network Underlying Mammalian Cortical Area Development. PLoS Computational Biology 6(9): e1000936.

Kauffman, S. (1995). At home in the universe: The search for laws of complexity. London: Penguin Books.

Hinton & Nolan (1987) How learning can guide evolution. Complex Systems 1: 495-502.

Greig et al., (2013) Molecular logic of neocortical projection neuron specification, development and diversity. Nature Neuroscience Reviews, 14: 755.

Project Number: 109

Title: Modelling thermoregulatory huddling

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Rodents are a very important model in developmental neuroscience. Current attempts to simulate e.g., rat brain development often neglect the fact that rat brains develop in rat bodies to help them to do ratty things! One of the most important ratty things is huddling with littermates to keep warm. In the first postnatal weeks when the cortex is wiring itself up, huddling is perhaps the most important source of correlation between sensory modalities. For example, turning to huddle with a warm littermate on the right provides a leftward optic flow that is correlated with tactile input to the right of the body, an increase in thermal reward, and increases in the sounds and smells emitted by the littermate etc. The aim of this project is to develop a simulation of a virtual rat litter, in order to synthesize these patterns of multisensory correlation under different huddling conditions (i.e., at different temperatures), and to explore how different huddling conditions affect simulated brain development. The idea is to investigate whether self-organising models of cortical map development (see Bednar and Wilson, 2015 for a primer) can learn to exploit these correlations to make better huddlers.

Suitability: This project will be fun for students who can program, at least in python (and preferably in c++).

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Glancy J, Gross R, Stone JV, Wilson SP (2015) A self-organising model of thermoregulatory huddling. PLoS Computational Biology 11(9): e1004283. doi:10.1371/journal.pcbi.1004283

Wilson SP. (2017) Modelling the emergence of rodent filial huddling from physiological huddling. Royal Society Open Science, 4: 170885.

Project Number: 110

Title: The effect of cortical boundary shape on the emergence of cortical feature maps

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Stimulus-driven self-organisation represents the current best theory of the emergence of cortical feature maps. Continuous maps of visual orientation preference that match essentially all existing data on biological maps can be reproduced by computational models such as LISSOM and GCAL (Stevens et al., 2013) that represent Hebbian learning, short-range excitatory interactions and long-range inhibitory interactions between neurons on a cortical sheet. We have been developing software that allows these algorithms to be simulated on cortical sheets with arbitrary boundary shapes. The aim of this project is to investigate whether such models can also account for the alignment of orientation preference map structure with the boundary shape (iso-orientation contours tend to intersect the boundary at right angles).

Suitability: This project is suited to students with a willingness to learn to programme in c++ and python.

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Stevens JLR, Law JS, Antolʹık J, Bednar JA. Mechanisms for stable, robust, and adaptive development of orientation maps in the primary visual cortex. The Journal of Neuroscience. 2013; 33(40):15747– 15766.

Wilson SP, Bednar JA. What, if anything, are topological maps for? Developmental Neurobiology. 2015; 75(6):667–681.

Project Number: 111

Title: A comparison of EEG signal complexity measures

Supervisor/s: Dr Myles Jones

Location: Cathedral Court

Outline: Complexity of resting state and stimulus evoked EEG signals has been shown to differ in neurodevelopmental conditions such as Autism (Milne et al., 2019). However, there are many ways to estimate the complexity of a signal (see Parameshwaran et al., 2019) with Parameshwaran et al., (2019) suggesting a novel metric ('waveform complexity') provides superior correlations to task performance than other measures. As such the current investigation seeks to examine which of the different metrics outlined in Parameshwaran et al., (2019) display greater differences in previously collected EEG data from those with Autistic Spectrum Conditions compared to control subjects (Milne et al., 2019).

Suitability: No specific requirements

Key references:
Milne, E., Gomez, R., Giannadou, A., & Jones, M. (2019). Atypical EEG in autism spectrum disorder: Comparing a dimensional and a categorical approach. Journal of Abnormal Psychology, 128(5), 442-452. doi:10.1037/abn0000436

Parameshwaran, D., Subramaniyam, N. P., & Thiagarajan, T. C. (2019). Waveform complexity: A new metric for EEG analysis. J Neurosci Methods, 325, 108313. doi:10.1016/j.jneumeth.2019.108313

Project Number: 112

Title: Effects of systemic inflammation on brain vascular function

Supervisor/s: Chris Martin

Location: Alfred Denny Labs and Cathedral Court

Outline: The regulation of blood flow in the brain according to the metabolic demands of active brain cells is a subject of great importance for two research areas: (i) the understanding of functional brain imaging data; (ii) the role of altered blood flow regulation in a range of neurodegenerative and neuropsychiatric diseases. In Sheffield we use a range of in-vivo methods in animal models (including imaging and electrophysiology) to study brain blood flow regulation in detail. There are a number of specific questions being asked in the lab that can form the basis of an MSc project, including: (i) how does systemic inflammation (an immune response to injury or illness) affect brain blood flow regulation; (ii) how do alterations in brain serotonin function (as implicated in affective/mood disorders) affect blood flow regulation; (ii) how do alterations in the function of other major neuromodulatory neurotransmitter systems (dopamine, acetylcholine) affect brain blood flow regulation. There are a range of specific hypotheses that can be tested for each project area.

Suitability: Experience of, or willingness to learn to use MatLab for data analysis would be useful. Projects can be tailored for either students with more advanced computational/analysis/modelling skills, or for those who wish to focus in more detail on neurobiological issues. Getting hands on experience of animal work is restricted due to Home Office (legal) regulations, but students will be able to spend time in the lab and become familiar with the environment, methods and procedures.

Key references:

Spain, Aisling, et al. Neurovascular and neuroimaging effects of the hallucinogenic serotonin receptor agonist psilocin in the rat brain. Neuropharmacology 99 (2015): 210-220. [describe some of the key methodology and approach used in the lab]

Brezzo, Gaia, et al. Acute effects of systemic inflammation upon neurovascular unit and cerebrovascular function. bioRxiv (2018): 498089.

Jeon, Sang Won, and Yong-Ku Kim. The role of neuroinflammation and neurovascular dysfunction in major depressive disorder. Journal of inflammation research 11 (2018): 179. [optional, skip to the neurovascular sections]

Project Number: 113

Title: Neurovascular coupling and aging

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: The brain is energetically expensive, accounting for only 2% of the body's mass, it uses 20% of the body's resting energy. In order to maintain normal brain function, it is essential that neuronal energy demands are met by changes in local blood flow. This matching of energy supply and demand is accomplished through a mechanism termed neurovascular coupling. The changes in blood flow associated with neural activity are the basis of functional imaging signals such as BOLD fMRI.
Evidence suggests that neurovascular coupling is dysfunctional in both aging and neurodegenerative diseases (e.g. Alzheimer's disease). Such changes in neurovascular function could contribute to cognitive decline which is associated with aging. This project will analyse an existing dataset in order to elucidate further the changes which occur in neurovascular function during aging. Data collection involved multimodal techniques (e.g. 2D-Optical Imaging Spectroscopy to measure haemodynamic changes, multi-channel electrophysiology to concurrently measure neural activity) in mice of different ages (6-24 months old). Students may view data collection if they wish.

This research will (1) increase our understanding of normal brain function, (2) elucidate neurovascular dysfunctions which occur in aging, (3) increase our ability to accurately interpret functional imaging signals and (4) reveal potential therapeutic loci for neurodegenerative diseases.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Attwell et al., 2010 Nature 468

Aanerud et al., 2012 JCBFM 32

farkas & Luiten, 2001 Prog Neurobiol. 64

Girouard & Iadecola, 2006 J Appl Physiol. 100

Project Number: 114

Title: Using optogenetics to investigate the role of cortical interneurons in neurovascular coupling.

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a vital brain mechanism ensuring that neuronal energy demands are met by dynamic changes in local blood flow. This mechanism underlies functional neuroimaging techniques such as BOLD fMRI and may be dysfunctional in neurodegenerative diseases.
We have previously combined a cell-specific optogenetic approach with 2-dimensional optical imaging spectroscopy (2D-OIS) and electrophysiology in anaesthetized mice to demonstrate that specific activation of single populations of cortical interneurons (those expressing somatostatin [SST] or neuronal nitric oxide synthase [nNOS]) is sufficient to elicit robust haemodynamic responses. Furthermore we have demonstrated that, in the case of nNOS-expressing interneurons, this increase in blood volume occurs in the absence of a large change in neuronal activity.
By further understanding the influence of these cells on normal network physiology and haemodynamic correlates we can not only begin to decipher how interneurons may contribute to disease processes but also improve our ability to interpret perfusion-based neuroimaging signals.
This project will involve analysis of existing datasets, using MATLAB. Students may view data collection if they wish.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Cauli B., et al. (2004) J. Neurosci. 24: 8940-9

Cauli B. & Hamel E. (2010) Front. Neuroenergetics 2: 9

Lee et al. (BiorXiv) https://doi.org/10.1101/550269

Uhlirova H., et al. (2016) Elife 5: e14315

Anenberg E., et al. (2015) J Cereb Blood Flow Metab 35: 1579-1586

Project Number: 115

Title: Trial-to-trial variability in human EEG recordings during visual stimulation and behaviour

Supervisor/s: Robert Schmidt and Elizabeth Milne

Location: Cathedral Court

Outline: In this project you will analyse EEG data recorded in humans performing a simple behavioural task. In the task a visual checkerboard stimulus was presented to the participants, who then had to respond to the offset of the stimulus with a button press. To what degree does neural activity reflect different aspects of the task? To address this you will apply several basic EEG analysis methods such as time-frequency analysis using spectrograms. Furthermore, you will examine neural variability, e.g. in the context of how neural oscillations before a trial affect the neural responses to the visual stimulus. The goal is to identify neural variability that correlates with behavioural variability (i.e. reaction times; how quickly the participants pressed the button). The project is suited for a student interested in the analysis and visualisation of large data sets (in this case many, recording channels, experimental trials and participants).

Suitability: Programming and data analysis skills (e.g. based on PSY6309)

Key references:

Becker, R., Ritter, P., & Villringer, A. (2008). Influence of ongoing alpha rhythm on the visual evoked potential. Neuroimage, 39(2), 707-716.

Leventhal, D. K., Gage, G. J., Schmidt, R., Pettibone, J. R., Case, A. C., & Berke, J. D. (2012). Basal ganglia beta oscillations accompany cue utilization. Neuron, 73(3), 523-536.

Makeig, S., Delorme, A., Westerfield, M., Jung, T. P., Townsend, J., Courchesne, E., & Sejnowski, T. J. (2004). Electroencephalographic brain dynamics following manually responded visual targets. PLoS biology, 2(6), e176.

Project Number: 116

Title: Design your own fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: You can soley, or as a part of a group, come up with an experimental question that you would like to investigate using fMRI. This can be an original idea, or a study that aims to extend or solely validate/replicate a previous study. You will be responsible for designing the task, piloting it, acquiring and analyzing the fMRI data. Any questions please get in touch.

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Amaro, E., Jr. & Barker, G. J. Study design in fMRI: basic principles. Brain Cogn, 2006, 60, 220-232

Project Number: 117

Title: Effect of negative and positive social feedback – An fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: This fMRI study has been designed to examine the effect and neural substrates of how we react to individuals that have been associated with either positive and negative outcomes or social feedback. The aim is to understand how such events shape/bias our emotional and decision making responses to different individuals, and the brain regions involved. You will get invaluable training and insight of fMRI experimental design and analysis methodologies. In this study you will develop the experimental paradigm, and acquire fMRI data from adult participants. The aim is to work as a group on these aspects, and once the data has been acquired, work individually to analyse the fMRI data on the questions that interest you. Any questions please get in touch

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Wiggert, N., Wilhelm, F. H., Boger, S., Georgii, C., Klimesch, W., & Blechert, J. (2017). Social Pavlovian conditioning: Short- and long-term effects and the role of anxiety and depressive symptoms. Social Cognitive and Affective Neuroscience, 12(2), 329-339. doi:10.1093/scan/nsw128

Project Number: 118

Title: An examination of parvalbumin expressing interneurons in murine models of autism spectrum disorder.

Supervisor/s: Dr Timothy Riley; Dr Martin Clark (external collaborator)

Location: Alfred Denny; Cathedral Court

Outline: Emerging evidence suggests that altered interneuron levels may underpin the behavioral deficits that are central to the symptoms of autism spectrum disorder (ASD). Specifically, it has been suggested that one of genetic networks that is associated with ASD may code for a downregulation of parvalbumin (PV) expressing interneurons in the basal ganglia. Recent evidence utilising PV knockout mouse models (mice that have been genetically modified to express limited levels of PV interneurons), shows that these mice display the core behavioural symptoms present in human ASD. Further, electrophysiological evidence in this model suggests that these symptoms may present in part due to altered synaptic transmission resulting from downregulated PV expression. Thus while it has been shown that altered PV expression is associated with ASD like symptoms, it has yet to be established if ASD-like symptoms are associated with altered PV expression. The proposed study would aim to expand previous findings to consider if PV interneuron expression is altered in validated mouse models of ASD, focusing on differences in the expression profiles of PV interneurons in the dorsal striatum and, potentially, other regions of the basal ganglia. This project will utilise an ex-vivo immunohistochemistry methodology; students working on this project, will slice, stain, and examine the brains of mouse models of ASD under supervision.

Suitability: This project is best suited for students with an interest in systems neuroscience who want to gain firsthand experience of lab work.

Key references:

Wöhr, M., Orduz, D., Gregory, P., Moreno, H., Khan, U., Vörckel, K. J., Schwaller, B. (2015). Lack of parvalbumin in mice leads to behavioral deficits relevant to all human autism core symptoms and related neural morphofunctional abnormalities. Translational Psychiatry, 5, e525. doi:10.1038/tp.2015.19

Fuccillo, M. V. (2016). Striatal Circuits as a Common Node for Autism Pathophysiology. Frontiers in Neuroscience, 10, 27.

Garas, F. N., Shah, R. S., Kormann, E., Doig, N. M., Vinciati, F., Nakamura, K. C., Sharott, A. (2016). Secretagogin expression delineates functionally-specialized populations of striatal parvalbumin-containing interneurons. eLife, 5. doi:10.7554/eLife.16088

Project Number: 119

Title: Neurovascular breakdown in Dementia and Atherosclerosis

Supervisor/s: Dr Jason Berwick, Dr Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a homeostatic mechanism that is responsible for increasing cerebral blood flow in response to neuronal activity to ensure the brain is supplied with enough oxygen and glucose to function properly. A new idea called the neurovascular degeneration hypothesis suggests a breakdown in neurovascular coupling is an important factor in neurodegenerative diseases, especially Alzheimer's. Our laboratory has been investigating neurovascular breakdown in a transgenic Alzheimer's mice for a number of years. To date our findings actually show that neurovascular coupling is preserved in the model (J20) we use, against other findings in the field. However, recently we have developed a new model in which we give our J20 mouse an induced form of Atherosclerosis. In this model neurovascular coupling appears to be significantly affected. New data is currently being collected and will be analysed as part of this project.

Suitability: The students will observe data collection and will then use Matlab to analyse the results. Having the ability to write and edit code would be beneficial to the project. However, most core code already exists for data analysis

Key references:

Ameen-Ali K, Simpson JE, Wharton SB, Heath PR, Sharp P, Brezzo G, Berwick J (2019) The time course of recognition memory impairment and glial pathology in the hAPP-J20 mouse model of Alzheimer's disease. Journal of Alzheimer’s Disease 68(2):609-624.

Shabir O, Berwick J, Francis SE. (2018) Neurovascular dysfunction in vascular dementia, Alzheimer’s and atherosclerosis. BMC Neuroscience 19:62.

Ameen-Ali KE, Wharton SB, Simpson JE, Heath PR, Sharp P, Berwick J (2017). Review: Neuropathology and behavioural features of transgenic murine models of Alzheimer's disease. Neuropathology and Applied Neurobiology 43: 553-570.

Sharp PS, Shaw K, Boorman L, Harris S, Kennerley AJ, Azzouz M, Berwick J. (2015). Comparison of stimulus-evoked cerebral hemodynamics in the awake mouse and under a novel anesthetic regime. Scientific Reports 12621 doi:10.1038/srep12621.

Project Number: 131

Title: Practice effects on prioritisation of representations in working memory

Supervisor/s: Claudia von Bastian

Location: Cathedral Court

Outline: Working memory maintains representations and makes them available for ongoing cognitive processing, thereby building the basis for complex cognition. The capacity of working memory is on average limited to four items; in any given moment, however, only a single representation can be processed by focusing attention on it. To process a series of information elements, the focus of attention is shifted from one representation to the next. Shifting attention between representations produces measurable reaction time costs, so prioritising representations is critical. Retro-cues can be used to experimentally manipulate prioritisation of representations by indicating which representation will be relevant next. This project investigates how practice affects the prioritisation of representations in working memory by reanalysing data from an existing larger-scale study (De Simoni & von Bastian, 2018). In this study, 59 participants practiced four working memory tasks in 20 sessions spread over five weeks. In half of the trials, a cue indicated which item in working memory had to be processed next, whereas no such cue was presented in the other half of trials. The goal is to examine how the difference between these conditions develops over sessions, and whether any changes observed are related to changes in other cognitive abilities (e.g. executive functions).

Suitability: Strong interest in theories of human cognition; interest in working with a large data set. The analytical part of this project can be scaled to suit different skill levels and interests.

Key references:

De Simoni, C., & von Bastian, C. C. (2018). Working memory updating and binding training: Bayesian evidence supporting the absence of transfer. Journal of Experimental Psychology: General, 147(6), 829–858. https://doi.org/10.1037/xge0000453

Myers, N. E., Stokes, M. G., & Nobre, A. C. (2017). Prioritizing information during working memory: Beyond sustained internal attention. Trends in Cognitive Sciences, 21(6), 449-461. doi: 10.1016/j.tics.2017.03.010

Oberauer, K., & Hein, L. (2012). Attention to information in working memory. Current Directions in Psychological Science 21, 164-170. doi: 10.1177/0963721412444727

Project Number: 138

Title: Benefits of playing action videogames on multiple-object tracking: An fMRI study

Supervisor/s: Claudia von Bastian

Location: Cathedral Court

Outline: Previous research has shown that playing action videogames has beneficial effects on different mechanisms of attention such as attention to time, space, and objects (Bavelier & Green, 2019). For instance, action videogame players outperformed non-videogame players in tracking multiple moving objects (Green & Bavelier, 2006; Trick et al., 2005). In this task, blue and yellow cartoon faces are moving around a screen and participants are told to keep track of the blue faces. All the faces then change colour to yellow, but volunteers are asked to keep track of the faces that were initially blue (Green & Bavelier, 2006). After several seconds they are then asked to click on those faces. The goal of this project is to understand the underlying neural mechanisms of the benefits of playing action videogames on tracking multiple moving objects. For this purpose, participants will complete a multiple-object tracking task while brain imaging data are recorded, and we will analyse group differences in the fronto-parietal network. This project will be conducted in collaboration with Dr Julia Foecker (University of Lincoln).

Suitability: This project is suitable only for students trained in fMRI neuroimaging methods, i.e., students who have studied Neuroimaging 1 and 2 modules.

Key references:

Bavelier, D., Achtman, R. L., Mani, M., & Föcker, J. (2012). Neural bases of selective attention in action video game players. Vision Research, 61, 132-143.

Bavelier, D., & Green, C. S. (2019). Enhancing Attentional Control: Lessons from Action Video Games. Neuron, 104(1), 147-163.

Green, C. S., & Bavelier, D. (2006). Effect of action video games on the spatial distribution of visuospatial attention. Journal of Experimental Psychology: Human Perception and Performance, 32(6), 1465.

Trick, L. M., Jaspers-Fayer, F., & Sethi, N. (2005). Multiple-object tracking in children: The Catch the Spies task. Cognitive Development, 20(3), 373-387.

Project Number: 140

Title: Relating brain structure to the 2D:4D ratio

Supervisor/s: Dr Iain Croall, Prof Nigel Hoggard

Location: Academic Unit of Radiology, Royal Hallamshire Hospital

Outline: The 2D:4D ratio is the ratio between the length of the second and fourth digits on a person's hand (i.e. the index and ring finger). This ratio has been the focus of study in psychological research for some time as it shows correlations with a number of interesting outcomes from personality traits to incidence of serious psychiatric disorders. The mechanism of these relationships is not fully understood, but is hypothesised to be because the ratio acts as a stand-in marker of testosterone exposure in the womb. Despite this previous psychological research implying a link between brain structure and the 2D:4D ratio, surprisingly few studies have directly examined relationships between the two.
This project will use pre-existing T1-weighted (i.e. structural) MRI scans of healthy volunteers to conduct a series of volumetric analyses, linking together the size of different brain regions to the 2D:4D ratio. The student will gain experience using a number of image processing packages which are popular in clinically-based neuroimaging research (e.g. SPM, FSL).

Suitability: The project should be suitable for a majority of students. The methodological focus will be on image processing and analysis, which will involve work using SPM (which operates from Matlab) and FSL (which operates on a computer running a Linux operating system). Although some coding skills are desirable they are not essential; these are accessible software packages and all work will be achievable using either GUIs or simple instructions to operate a command line. This project should appeal to students with an interest in the physiology of the brain and how this impacts on a variety of outcomes. As the work will take place within a multi-disciplinary team which has a strong clinical focus, it is further suited to someone who is drawn to this setting.

Key references:
A review of the 2D:4D ratio: Jeevanandam S. & Muthu P.K. (2016). 2D:4D Ratio and its Implications in Medicine, J Clin Diagn Res. 10(12), doi: 10.7860/JCDR/2016/21952.9000

The student would be encouraged to do some reading around volumetric analysis methods of T1-weighted MRI scans, for example regional analyses of segmented brain structures, or the global voxel-based morphometry technique.

Project Number: 146

Title: Assessing functional somatotopy during active and passive hand use

Supervisor/s: Hannes Saal and Laura Edmondson, in collaboration with Tamar Makin (UCL) and Daan Wesselink (Oxford)

Location: Pam Liversidge Building

Outline: Modern imaging techniques allow examination of the somatosensory homunculus in unprecedented detail. A lot of attention has been devoted to the representation of the hand, which occupies a large fraction of somatosensory cortex. This region shows activity both during active hand movement, such a wiggling a finger, and during passive stimulation, such as when a finger is touched by a probe. Previous studies often assume that the representation of the hand is the same, whether probed in the active or passive case. Conversely, the differing nature of the inputs (thalamocortical in the passive and intra-cortical in the active case) suggest that cortical representation might differ. Here, we test this idea using an existing data set of detailed activation maps covering primary somatosensory (S1) and motor (M1) cortex collected using a high-field scanner under both active and passive conditions. The student will use typical measures for interrogating somatotopy such as BOLD activation, area sizes, finger distances and RSA to compare the effects of active and passive stimulation.

Suitability: This project is suitable for a student having taken Neuroimaging 1 and 2; willingness to learn some basic programming skills are welcome!

Key references:
Martuzzi, R., van der Zwaag, W., Farthouat, J., Gruetter, R., & Blanke, O. (2014).

Human finger somatotopy in areas 3b, 1, and 2: A 7T fMRI study using a natural stimulus. Human Brain Mapping, 35(1), 213–226. Ejaz N., Hamada M., Diedrichsen J. (2015).

Hand use predicts the structure of representations in sensorimotor cortex. Nat Neurosci. 18. Berlot, E., Prichard, G., O'Reilly, J., Naveed, E., & Diedrichsen, J. (2018).

Ipsilateral finger representations in the sensorimotor cortex are driven by active movement processes, not passive sensory input. Journal of neurophysiology.

MSc Cognitive and Computational Neuroscience Projects

Project Number: 101

Title: BYOM - Bring Your Own Model!

Supervisor/s: Hannes Saal, Stuart Wilson, Robert Schmidt

Location: Cathedral Court / Pam Liversidge Building

Outline: You already have an exciting idea for a computational model that you would like to investigate for your dissertation project? Is that idea more specific than just e.g. ‘modelling memory’ or ‘modelling the basal ganglia’? If so, then we are happy to discuss your idea in more detail to see whether it can be turned into a dissertation project. We would expect that you present your model idea in a 1-page written summary, and explain how you will use the model to answer a specific research question. Ideally, your model should be based on a published model in the scientific literature and you should be able to implement it with your current programming skills. The topic should address a current research area of computational neuroscience.

Suitability: Programming and modelling skills (e.g. based on PSY6307 and PSY6309)

Key references: N/A

Project Number: 102

Title: Big data on learning

Supervisor/s: Tom Stafford

Location: Flexible

Outline: I (Tom) have access to large existing data sets which contain the potential to show skill development on real-world tasks for large numbers of people (i.e. n>1,000,000 in domains of chess and online video games). Using theory from the cognitive science of learning and advanced statistical models and/or data visualisation techniques we will test theories of what makes learning most effective. Can we look at how people practice and relate this to the level of skill they reach? The ambition will be to design more effective learning practices. You will have an opportunity to work with the theory of the psychology of learning and a skill set encompassing state-of-the-art open-source analytics tools.

Suitability: Knowledge of R or Python or a strong willingness to learn these

Key references:
Stafford, T. & Haasnoot, E. (2017). Testing sleep consolidation in skill learning: a field study using an online game. Topics in Cognitive Science. 9(2), 485-496.

Project Number: 103

Title: Microsaccades and ADHD/ASD

Supervisor/s: Tom Stafford

Location: Mushroom Lane & Cathedral Court

Outline: Attention Deficit Hyperactivity Disorder (ADHD) is the most prevalent neurodevelopmental disorder, however the neural changes that underlie the disorder are poorly understood. Recent evidence suggests that a midbrain structure, the superior colliculus, is an important dysfunctional locus in the disorder. The superior colliculus plays a central role in the generation of eye movements, amongst them microsaccades (small amplitude saccades made during fixation), and we have recently shown that microsaccade rate positively correlates with ADHD-type symptoms in a non-clinical adult population, suggestive of a 'hyper-active' colliculus (Panagiotidi et al., 2017). The project we envisage will develop testing of whether it is possible to track changes in microsaccade rate over time in individual participants (Hampsey et al, submitted). In particular, we would like to see if response to caffeinated drinks affects microsaccade rate. Caffeine is a dopamine agonist, and dopamine plays an important functional role in both attention and collicular function). If it is possible to measure the time-response function using microsaccades then this is an important proof-of-concept for testing and developing pharmacotherapies in ADHD which are based on the collulicar hypersensitive hypothesis.

Suitability: Technical aptitude (eye-tracking) and experimental design skills required

Key references: Panagiotidi, M., Overton, P.G., Stafford, T. (2017). Increased microsaccade rate in individuals with ADHD traits. Journal of Eye Movement Research. 10,1
Hampsey, E., Overton, P.G., Stafford, T. (submitted). Microsaccade rate as a measure of drug response. https://psyarxiv.com/r6duk

Project Number: 104

Title: Cognitive Mapping versus Associative accounts of spatial learning in Virtual Reality

Supervisor/s: Stuart Wilson

Location: Pam Liversidge (experiments will take place in the VR lab in the Mappin Mining Block)

Outline: Is spatial learning distinct from other forms of learning? According to associative learning theories, when we encounter new information, whether temporal or spatial, that information is processed according to the same associative mechanisms. In contrast, according to cognitive mapping theory, when we explore a new environment we automatically construct a representation of that environment in which all distinctive landmarks, together with the geometric relationships between those landmarks, are stored. A mental representation of the environment in this structure can be employed to solve novel spatial problems. As such, the mechanisms that underpin spatial learning are presumed to be distinct from those that underpin non-spatial learning Cognitive mapping and associative learning theories make a number of different predictions about the way in which humans and other animals learn about space. For example, associative learning theories predict cue-interaction effects, such as blocking and overshadowing, whereas cognitive mapping theory does not, and cognitive mapping theory predicts that animals can automatically compute novel short-cut routes whereas associative learning does not. The aim of this project is to test the predictions of these two theories, by reproducing experimental designs in either cue-competition or short-cutting that have been well established in the classic animal learning literature, using human participants navigating environments experienced via Virtual Reality. See Alexander, Wilson, Wilson (2009) and Wilson & Wilson (2018 - in press) for examples of studies in this area.

Suitability: This project will involve the design and creation of new Virtual Environments using Unity 3D software. You will recruit participants, collect data in the Sheffield Robotics / INSIGNEO Virtual Reality and Motion Capture Lab in the Mappin Mining Block, and you will perform statistical analyses to test for short-cutting and/or cue-competition. This project is well suited to an experimental psychologist with an interest in computer-aided design or computer gaming. Students with ideas for constructing computational models of spatial learning to explain the existing data are also welcome to apply.

Key references:

O'Keefe J, Nadel L. The hippocampus as a cognitive map. Oxford University Press: Oxford; 1978.

Alexander T, Wilson SP, Wilson PN. (2009) Blocking of spatial learning based on shape. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(3):694–708.

Olton DS. (1978) Mazes, maps, and memory. American Psychologist, 34(7):583–596.

Pearce JM. (2009) The 36th Sir Frederick Bartlett Lecture: An associative analysis of spatial learning. The Quarterly Journal of Experimental Psychology, 62(9):1665–1684.

Wilson SP, Wilson PN (2018) Failure to demonstrate short-cutting in a replication and extension of

Tolman et al.'s spatial learning experiment with humans. PLoS ONE X(Y): e0208794.

Project Number: 105

Title: Telepresence immersion in an animal-like robot

Supervisor/s: Stuart Wilson Tony Prescott (Computer Science and Sheffield Robotics)

Location: Pam Liversidge Building

Outline: We work as part of Sheffield Robotics on biomimetic robotics, with a particular focus on brain-inspired computing, active sensing, scene understanding, episodic and spatial memory, social cognition and human-robot interaction. We are interested in the use of robots as telepresence devices for remote action in work and entertainment settings, and have created various telepresence interfaces for physical robots using virtual reality head-sets and different forms of body tracking (see Martinez-Hernandez et al., 2017). This project would explore whether we can give people a convincing immersive experience in a non-humanoid robot using the MiRo animal-like robot. As well as developing the telepresence system projects could explore its psychological impact. What is the experience of being immersed in a non-humanoid robot? Are there after-effects?

Suitability: Students should have reasonable programming skills (ideally Python or C++) and an interest in societal applications of robotics. Some knowledge of psychology and/or experimental design would be useful. No prior familiarity with robots in needed.

Key references:

Martinez-Hernandez, U., Boorman, L. W. and Prescott, T. J. (2017). Multisensory Wearable Interface for Immersion and Telepresence in Robotics. IEEE Sensors Journal, 17(8), 2534-2541. doi:10.1109/JSEN.2017.2669038

Mitchinson, B. and Prescott, T. J. (2016). MIRO: A Robot Mammal with a Biomimetic Brain-Based Control System. Living Machines V: Biomimetic and Biohybrid Systems, LNCAI 9793, pp. 179-191.

Project Number: 107

Title: Reaction-diffusion modelling of cortical arealization

Supervisor/s: Stuart Wilson and Sebastian James

Location: Pam Liversidge Building

Outline: Morphogenesis (pattern formation) in biological systems can be understood in terms of the tension between local excitatory interactions between cells and longer-ranging inhibitory interactions. Reaction-diffusion models, based on the ideas of Alan Turing, provide a formalism for understanding how this tension can lead to different patterns, e.g., resulting in the stripes versus spots of colour we see on animal skins. Similar processes describe how patterning in the brain occurs, in particular in the developing neocortex. The aim of this project is to investigate how genetic constraints acting on reaction-diffusion processes shape the patterning of the developing neocortex to result in differences in the relative size and shape of the primary cortical areas (A1, V1, S1 etc.). The two papers below by Bard Ermentrout outline a) a reaction-diffusion approach to between-area patterning in a 1D model of cortical development, and b) a reaction-diffusion approach to within-area patterning in a 2D model of cortical development. We have been combining these two approaches to create a reaction-diffusion model with which to investigate between-area pattern formation on a simulated 2D cortical sheet. The aim of this project is to calibrate the model to data obtained by our collaborator lab at University California Davis (Leah Krubitzer), who have been experimentally manipulating the size of the cortical sheet and the sensory experiences of developing animals across a range of mammalian species

Suitability: The mathematics (partial differential equations) and computing (c++ and python) foundations of this project are now fairly well established, and as such projects can be designed around the mathematical/computing expertise and interests of the student.

Key references:

Karbowski, Ermentrout (2004) Model of the Early Development of Thalamo-Cortical Connections and Area Patterning via Signaling Molecules. Journal of Computational Neuroscience 17, 347–363

Ermentrout B, Simons DJ, Land PW (2009) Subbarrel Patterns in Somatosensory Cortical Barrels Can Emerge from Local Dynamic Instabilities. PLoS Computational Biology 5(10): e1000537

Krubitzer, Dooley (2013) Cortical plasticity within and across lifetimes: how can development inform us about phenotypic transformations? Frontiers in Human Neuroscience, 7 (620), 1-14.

Project Number: 108

Title: Artificial gene regulatory networks

Supervisor/s: Stuart Wilson and Daniel Whiteley

Location: Pam Liversidge Building

Outline: We have been using principles from Artificial Neural Networks research to construct models of how gene-regulatory networks evolve and develop. Specifically, we are interested in the networks that give rise to the graded patterns of gene expression that guide development of thalamocortical axons and ultimately specify the primary cortical fields (V1, S1, A1 etc.). In this project we will investigate how constraints on the network architecture (e.g., feed-forward versus fully connected recurrent networks) might account for the range of gene expression patterns observed in real gene networks, using a new technique we have been developing for disabling network learning to represent the effects of gene knock-out experiments. Depending on student interest, there is also scope for exploring these problems further using evolutionary algorithms.

Suitability: The focus of this project can be shifted depending on the expertise/interests of the student either to focus on algorithm development on the reasonably small-scale, or to run more intensive simulations. Willingness to learn c++ and/or python is required.

Key references:

Giacomantonio CE, Goodhill GJ (2010) A Boolean Model of the Gene Regulatory Network Underlying Mammalian Cortical Area Development. PLoS Computational Biology 6(9): e1000936.

Kauffman, S. (1995). At home in the universe: The search for laws of complexity. London: Penguin Books.

Hinton & Nolan (1987) How learning can guide evolution. Complex Systems 1: 495-502.

Greig et al., (2013) Molecular logic of neocortical projection neuron specification, development and diversity. Nature Neuroscience Reviews, 14: 755.

Project Number: 109

Title: Modelling thermoregulatory huddling

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Rodents are a very important model in developmental neuroscience. Current attempts to simulate e.g., rat brain development often neglect the fact that rat brains develop in rat bodies to help them to do ratty things! One of the most important ratty things is huddling with littermates to keep warm. In the first postnatal weeks when the cortex is wiring itself up, huddling is perhaps the most important source of correlation between sensory modalities. For example, turning to huddle with a warm littermate on the right provides a leftward optic flow that is correlated with tactile input to the right of the body, an increase in thermal reward, and increases in the sounds and smells emitted by the littermate etc. The aim of this project is to develop a simulation of a virtual rat litter, in order to synthesize these patterns of multisensory correlation under different huddling conditions (i.e., at different temperatures), and to explore how different huddling conditions affect simulated brain development. The idea is to investigate whether self-organising models of cortical map development (see Bednar and Wilson, 2015 for a primer) can learn to exploit these correlations to make better huddlers.

Suitability: This project will be fun for students who can program, at least in python (and preferably in c++).

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Glancy J, Gross R, Stone JV, Wilson SP (2015) A self-organising model of thermoregulatory huddling. PLoS Computational Biology 11(9): e1004283. doi:10.1371/journal.pcbi.1004283

Wilson SP. (2017) Modelling the emergence of rodent filial huddling from physiological huddling. Royal Society Open Science, 4: 170885.

Project Number: 110

Title: The effect of cortical boundary shape on the emergence of cortical feature maps

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Stimulus-driven self-organisation represents the current best theory of the emergence of cortical feature maps. Continuous maps of visual orientation preference that match essentially all existing data on biological maps can be reproduced by computational models such as LISSOM and GCAL (Stevens et al., 2013) that represent Hebbian learning, short-range excitatory interactions and long-range inhibitory interactions between neurons on a cortical sheet. We have been developing software that allows these algorithms to be simulated on cortical sheets with arbitrary boundary shapes. The aim of this project is to investigate whether such models can also account for the alignment of orientation preference map structure with the boundary shape (iso-orientation contours tend to intersect the boundary at right angles).

Suitability: This project is suited to students with a willingness to learn to programme in c++ and python.

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Stevens JLR, Law JS, Antolʹık J, Bednar JA. Mechanisms for stable, robust, and adaptive development of orientation maps in the primary visual cortex. The Journal of Neuroscience. 2013; 33(40):15747– 15766.

Wilson SP, Bednar JA. What, if anything, are topological maps for? Developmental Neurobiology. 2015; 75(6):667–681.

Project Number: 111

Title: A comparison of EEG signal complexity measures

Supervisor/s: Dr Myles Jones

Location: Cathedral Court

Outline: Complexity of resting state and stimulus evoked EEG signals has been shown to differ in neurodevelopmental conditions such as Autism (Milne et al., 2019). However, there are many ways to estimate the complexity of a signal (see Parameshwaran et al., 2019) with Parameshwaran et al., (2019) suggesting a novel metric ('waveform complexity') provides superior correlations to task performance than other measures. As such the current investigation seeks to examine which of the different metrics outlined in Parameshwaran et al., (2019) display greater differences in previously collected EEG data from those with Autistic Spectrum Conditions compared to control subjects (Milne et al., 2019).

Suitability: No specific requirements

Key references:
Milne, E., Gomez, R., Giannadou, A., & Jones, M. (2019). Atypical EEG in autism spectrum disorder: Comparing a dimensional and a categorical approach. Journal of Abnormal Psychology, 128(5), 442-452. doi:10.1037/abn0000436

Parameshwaran, D., Subramaniyam, N. P., & Thiagarajan, T. C. (2019). Waveform complexity: A new metric for EEG analysis. J Neurosci Methods, 325, 108313. doi:10.1016/j.jneumeth.2019.108313

Project Number: 112

Title: Effects of systemic inflammation on brain vascular function

Supervisor/s: Chris Martin

Location: Alfred Denny Labs and Cathedral Court

Outline: The regulation of blood flow in the brain according to the metabolic demands of active brain cells is a subject of great importance for two research areas: (i) the understanding of functional brain imaging data; (ii) the role of altered blood flow regulation in a range of neurodegenerative and neuropsychiatric diseases. In Sheffield we use a range of in-vivo methods in animal models (including imaging and electrophysiology) to study brain blood flow regulation in detail. There are a number of specific questions being asked in the lab that can form the basis of an MSc project, including: (i) how does systemic inflammation (an immune response to injury or illness) affect brain blood flow regulation; (ii) how do alterations in brain serotonin function (as implicated in affective/mood disorders) affect blood flow regulation; (ii) how do alterations in the function of other major neuromodulatory neurotransmitter systems (dopamine, acetylcholine) affect brain blood flow regulation. There are a range of specific hypotheses that can be tested for each project area.

Suitability: Experience of, or willingness to learn to use MatLab for data analysis would be useful. Projects can be tailored for either students with more advanced computational/analysis/modelling skills, or for those who wish to focus in more detail on neurobiological issues. Getting hands on experience of animal work is restricted due to Home Office (legal) regulations, but students will be able to spend time in the lab and become familiar with the environment, methods and procedures.

Key references:

Spain, Aisling, et al. Neurovascular and neuroimaging effects of the hallucinogenic serotonin receptor agonist psilocin in the rat brain. Neuropharmacology 99 (2015): 210-220. [describe some of the key methodology and approach used in the lab]

Brezzo, Gaia, et al. Acute effects of systemic inflammation upon neurovascular unit and cerebrovascular function. bioRxiv (2018): 498089.

Jeon, Sang Won, and Yong-Ku Kim. The role of neuroinflammation and neurovascular dysfunction in major depressive disorder. Journal of inflammation research 11 (2018): 179. [optional, skip to the neurovascular sections]

Project Number: 113

Title: Neurovascular coupling and aging

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: The brain is energetically expensive, accounting for only 2% of the body's mass, it uses 20% of the body's resting energy. In order to maintain normal brain function, it is essential that neuronal energy demands are met by changes in local blood flow. This matching of energy supply and demand is accomplished through a mechanism termed neurovascular coupling. The changes in blood flow associated with neural activity are the basis of functional imaging signals such as BOLD fMRI.
Evidence suggests that neurovascular coupling is dysfunctional in both aging and neurodegenerative diseases (e.g. Alzheimer's disease). Such changes in neurovascular function could contribute to cognitive decline which is associated with aging. This project will analyse an existing dataset in order to elucidate further the changes which occur in neurovascular function during aging. Data collection involved multimodal techniques (e.g. 2D-Optical Imaging Spectroscopy to measure haemodynamic changes, multi-channel electrophysiology to concurrently measure neural activity) in mice of different ages (6-24 months old). Students may view data collection if they wish.

This research will (1) increase our understanding of normal brain function, (2) elucidate neurovascular dysfunctions which occur in aging, (3) increase our ability to accurately interpret functional imaging signals and (4) reveal potential therapeutic loci for neurodegenerative diseases.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Attwell et al., 2010 Nature 468

Aanerud et al., 2012 JCBFM 32

farkas & Luiten, 2001 Prog Neurobiol. 64

Girouard & Iadecola, 2006 J Appl Physiol. 100

Project Number: 114

Title: Using optogenetics to investigate the role of cortical interneurons in neurovascular coupling.

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a vital brain mechanism ensuring that neuronal energy demands are met by dynamic changes in local blood flow. This mechanism underlies functional neuroimaging techniques such as BOLD fMRI and may be dysfunctional in neurodegenerative diseases.
We have previously combined a cell-specific optogenetic approach with 2-dimensional optical imaging spectroscopy (2D-OIS) and electrophysiology in anaesthetized mice to demonstrate that specific activation of single populations of cortical interneurons (those expressing somatostatin [SST] or neuronal nitric oxide synthase [nNOS]) is sufficient to elicit robust haemodynamic responses. Furthermore we have demonstrated that, in the case of nNOS-expressing interneurons, this increase in blood volume occurs in the absence of a large change in neuronal activity.
By further understanding the influence of these cells on normal network physiology and haemodynamic correlates we can not only begin to decipher how interneurons may contribute to disease processes but also improve our ability to interpret perfusion-based neuroimaging signals.
This project will involve analysis of existing datasets, using MATLAB. Students may view data collection if they wish.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Cauli B., et al. (2004) J. Neurosci. 24: 8940-9

Cauli B. & Hamel E. (2010) Front. Neuroenergetics 2: 9

Lee et al. (BiorXiv) https://doi.org/10.1101/550269

Uhlirova H., et al. (2016) Elife 5: e14315

Anenberg E., et al. (2015) J Cereb Blood Flow Metab 35: 1579-1586

Project Number: 115

Title: Trial-to-trial variability in human EEG recordings during visual stimulation and behaviour

Supervisor/s: Robert Schmidt and Elizabeth Milne

Location: Cathedral Court

Outline: In this project you will analyse EEG data recorded in humans performing a simple behavioural task. In the task a visual checkerboard stimulus was presented to the participants, who then had to respond to the offset of the stimulus with a button press. To what degree does neural activity reflect different aspects of the task? To address this you will apply several basic EEG analysis methods such as time-frequency analysis using spectrograms. Furthermore, you will examine neural variability, e.g. in the context of how neural oscillations before a trial affect the neural responses to the visual stimulus. The goal is to identify neural variability that correlates with behavioural variability (i.e. reaction times; how quickly the participants pressed the button). The project is suited for a student interested in the analysis and visualisation of large data sets (in this case many, recording channels, experimental trials and participants).

Suitability: Programming and data analysis skills (e.g. based on PSY6309)

Key references:

Becker, R., Ritter, P., & Villringer, A. (2008). Influence of ongoing alpha rhythm on the visual evoked potential. Neuroimage, 39(2), 707-716.

Leventhal, D. K., Gage, G. J., Schmidt, R., Pettibone, J. R., Case, A. C., & Berke, J. D. (2012). Basal ganglia beta oscillations accompany cue utilization. Neuron, 73(3), 523-536.

Makeig, S., Delorme, A., Westerfield, M., Jung, T. P., Townsend, J., Courchesne, E., & Sejnowski, T. J. (2004). Electroencephalographic brain dynamics following manually responded visual targets. PLoS biology, 2(6), e176.

Project Number: 116

Title: Design your own fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: You can soley, or as a part of a group, come up with an experimental question that you would like to investigate using fMRI. This can be an original idea, or a study that aims to extend or solely validate/replicate a previous study. You will be responsible for designing the task, piloting it, acquiring and analyzing the fMRI data. Any questions please get in touch.

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Amaro, E., Jr. & Barker, G. J. Study design in fMRI: basic principles. Brain Cogn, 2006, 60, 220-232

Project Number: 117

Title: Effect of negative and positive social feedback – An fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: This fMRI study has been designed to examine the effect and neural substrates of how we react to individuals that have been associated with either positive and negative outcomes or social feedback. The aim is to understand how such events shape/bias our emotional and decision making responses to different individuals, and the brain regions involved. You will get invaluable training and insight of fMRI experimental design and analysis methodologies. In this study you will develop the experimental paradigm, and acquire fMRI data from adult participants. The aim is to work as a group on these aspects, and once the data has been acquired, work individually to analyse the fMRI data on the questions that interest you. Any questions please get in touch

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Wiggert, N., Wilhelm, F. H., Boger, S., Georgii, C., Klimesch, W., & Blechert, J. (2017). Social Pavlovian conditioning: Short- and long-term effects and the role of anxiety and depressive symptoms. Social Cognitive and Affective Neuroscience, 12(2), 329-339. doi:10.1093/scan/nsw128

Project Number: 118

Title: An examination of parvalbumin expressing interneurons in murine models of autism spectrum disorder.

Supervisor/s: Dr Timothy Riley; Dr Martin Clark (external collaborator)

Location: Alfred Denny; Cathedral Court

Outline: Emerging evidence suggests that altered interneuron levels may underpin the behavioral deficits that are central to the symptoms of autism spectrum disorder (ASD). Specifically, it has been suggested that one of genetic networks that is associated with ASD may code for a downregulation of parvalbumin (PV) expressing interneurons in the basal ganglia. Recent evidence utilising PV knockout mouse models (mice that have been genetically modified to express limited levels of PV interneurons), shows that these mice display the core behavioural symptoms present in human ASD. Further, electrophysiological evidence in this model suggests that these symptoms may present in part due to altered synaptic transmission resulting from downregulated PV expression. Thus while it has been shown that altered PV expression is associated with ASD like symptoms, it has yet to be established if ASD-like symptoms are associated with altered PV expression. The proposed study would aim to expand previous findings to consider if PV interneuron expression is altered in validated mouse models of ASD, focusing on differences in the expression profiles of PV interneurons in the dorsal striatum and, potentially, other regions of the basal ganglia. This project will utilise an ex-vivo immunohistochemistry methodology; students working on this project, will slice, stain, and examine the brains of mouse models of ASD under supervision.

Suitability: This project is best suited for students with an interest in systems neuroscience who want to gain firsthand experience of lab work.

Key references:
Wöhr, M., Orduz, D., Gregory, P., Moreno, H., Khan, U., Vörckel, K. J., Schwaller, B. (2015). Lack of parvalbumin in mice leads to behavioral deficits relevant to all human autism core symptoms and related neural morphofunctional abnormalities. Translational Psychiatry, 5, e525. doi:10.1038/tp.2015.19

Fuccillo, M. V. (2016). Striatal Circuits as a Common Node for Autism Pathophysiology. Frontiers in Neuroscience, 10, 27.

Garas, F. N., Shah, R. S., Kormann, E., Doig, N. M., Vinciati, F., Nakamura, K. C., Sharott, A. (2016). Secretagogin expression delineates functionally-specialized populations of striatal parvalbumin-containing interneurons. eLife, 5. doi:10.7554/eLife.16088

Project Number: 119

Title: Neurovascular breakdown in Dementia and Atherosclerosis

Supervisor/s: Dr Jason Berwick, Dr Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a homeostatic mechanism that is responsible for increasing cerebral blood flow in response to neuronal activity to ensure the brain is supplied with enough oxygen and glucose to function properly. A new idea called the neurovascular degeneration hypothesis suggests a breakdown in neurovascular coupling is an important factor in neurodegenerative diseases, especially Alzheimer's. Our laboratory has been investigating neurovascular breakdown in a transgenic Alzheimer's mice for a number of years. To date our findings actually show that neurovascular coupling is preserved in the model (J20) we use, against other findings in the field. However, recently we have developed a new model in which we give our J20 mouse an induced form of Atherosclerosis. In this model neurovascular coupling appears to be significantly affected. New data is currently being collected and will be analysed as part of this project.

Suitability: The students will observe data collection and will then use Matlab to analyse the results. Having the ability to write and edit code would be beneficial to the project. However, most core code already exists for data analysis

Key references:

Ameen-Ali K, Simpson JE, Wharton SB, Heath PR, Sharp P, Brezzo G, Berwick J (2019) The time course of recognition memory impairment and glial pathology in the hAPP-J20 mouse model of Alzheimer's disease. Journal of Alzheimer’s Disease 68(2):609-624.

Shabir O, Berwick J, Francis SE. (2018) Neurovascular dysfunction in vascular dementia, Alzheimer’s and atherosclerosis. BMC Neuroscience 19:62.

Ameen-Ali KE, Wharton SB, Simpson JE, Heath PR, Sharp P, Berwick J (2017). Review: Neuropathology and behavioural features of transgenic murine models of Alzheimer's disease. Neuropathology and Applied Neurobiology 43: 553-570.

Sharp PS, Shaw K, Boorman L, Harris S, Kennerley AJ, Azzouz M, Berwick J. (2015). Comparison of stimulus-evoked cerebral hemodynamics in the awake mouse and under a novel anesthetic regime. Scientific Reports 12621 doi:10.1038/srep12621.

Project Number: 128

Title: Modelling the effect of emotional and drug-related cues on response inhibition

Supervisor/s: Robert Schmidt and Matt Field

Location: Cathedral Court

Outline: How does our brain make decisions? Many aspects of decision-making, including response inhibition, have successfully been modelled using a simple description of accumulating processes growing towards a threshold. For example, two different processes might represent two different choices, and the process that reaches the threshold first is chosen. The time that the process took to reach the threshold can then be used to model reaction times. This has been used to describe behaviour and neural activity in a stop-signal task, in which a "Go" process races against a "Stop" process. In this project the student develops a novel computational model describing action suppression in the context of emotional and alcohol-related cues (Jones and Field, 2015). To do so the student will first implement a horse race model of stopping (e.g. Boucher et al., 2007) and then devise a new way to incorporate different types of stimuli (i.e. emotional and drug-related cues) and investigate their effect on inhibitory control. The results are relevant both for computational models of decision-making circuits and the neural basis of drug abuse.

Suitability: Programming and modelling skills (e.g. based on PSY6307, PSY6309)

Key references:
Boucher, L., Palmeri, T. J., Logan, G. D., & Schall, J. D. (2007). Inhibitory control in mind and brain: an interactive race model of countermanding saccades. Psychological Review, 114(2), 376.

Jones, A., & Field, M. (2015). Alcohol-related and negatively valenced cues increase motor and oculomotor disinhibition in social drinkers. Experimental and clinical psychopharmacology, 23(2), 122.

Schmidt, R., Leventhal, D. K., Mallet, N., Chen, F., & Berke, J. D. (2013). Canceling actions involves a race between basal ganglia pathways. Nature Neuroscience, 16(8), 1118-1124.

Project Number: 130

Title: Practice effects on decision-making using diffusion modelling

Supervisor/s: Claudia von Bastian

Location: Cathedral Court

Outline: The rate with which people can extract information from the environment is essential to human cognition and strongly related to fluid intelligence. Initial evidence suggests that this rate may be enhanced through practicing simple decision-making tasks. This project will test whether these preliminary findings can be replicated in another (already existing) data set. The data set is from 29 participants who completed 20 training sessions. Each training session comprised three tasks in which participants practiced making decisions as quickly and as accurately as possible (e.g. decide whether two words belonged to the same semantic category). To test whether this intensive practice induced broader cognitive benefits, the EZ diffusion model (Wagenmakers et al., 2007) will be used to estimate each participant's rate of extracting information (drift rate), response caution (boundary separation), and other processes such as motor execution (non-decision time). The goal is to examine whether these parameters change with practice (i.e. over the 20 sessions) and whether changes observed are associated with change in other cognitive abilities (e.g. fluid intelligence).

Suitability: Strong analytical skills and interest in computational modelling techniques; willingness to adjust R code used for the modelling procedure.

Key references:
Dutilh, G., Vandekerckhove, J., Tuerlinckx, F., & Wagenmakers, E. J. (2009). A diffusion model decomposition of the practice effect. Psychonomic Bulletin and Review, 16(6), 1026–1036. https://doi.org/10.3758/16.6.1026

Schmiedek, F., Oberauer, K., Wilhelm, O., Suess, H.-M., & Wittmann, W. W. (2007). Individual differences in components of reaction time distributions and their relations to working memory and intelligence. Journal of Experimental Psychology: General, 146(3), 414-429. doi: 10.1037/0096-3445.136.3.414

Schubert, A., Frischkorn, G. T., Hagemann, D., & Voss, A. (2016). Trait characteristics of diffusion model parameters. Journal of Intelligence, 4(3), 7. https://doi.org/10.3390/jintelligence4030007

Wagenmakers, E.-J., van der Maas, H. L. J., & Grasman, R. P. P. P. (2007). An EZ-diffusion model for response time and accuracy. Psychonomic Bulletin & Review, 14(1), 3–22. https://doi.org/10.3758/BF03194023

Project Number: 131

Title: Practice effects on prioritisation of representations in working memory

Supervisor/s: Claudia von Bastian

Location: Cathedral Court

Outline: Working memory maintains representations and makes them available for ongoing cognitive processing, thereby building the basis for complex cognition. The capacity of working memory is on average limited to four items; in any given moment, however, only a single representation can be processed by focusing attention on it. To process a series of information elements, the focus of attention is shifted from one representation to the next. Shifting attention between representations produces measurable reaction time costs, so prioritising representations is critical. Retro-cues can be used to experimentally manipulate prioritisation of representations by indicating which representation will be relevant next. This project investigates how practice affects the prioritisation of representations in working memory by reanalysing data from an existing larger-scale study (De Simoni & von Bastian, 2018). In this study, 59 participants practiced four working memory tasks in 20 sessions spread over five weeks. In half of the trials, a cue indicated which item in working memory had to be processed next, whereas no such cue was presented in the other half of trials. The goal is to examine how the difference between these conditions develops over sessions, and whether any changes observed are related to changes in other cognitive abilities (e.g. executive functions).

Suitability: Strong interest in theories of human cognition; interest in working with a large data set. The analytical part of this project can be scaled to suit different skill levels and interests.

Key references:

De Simoni, C., & von Bastian, C. C. (2018). Working memory updating and binding training: Bayesian evidence supporting the absence of transfer. Journal of Experimental Psychology: General, 147(6), 829–858. https://doi.org/10.1037/xge0000453

Myers, N. E., Stokes, M. G., & Nobre, A. C. (2017). Prioritizing information during working memory: Beyond sustained internal attention. Trends in Cognitive Sciences, 21(6), 449-461. doi: 10.1016/j.tics.2017.03.010

Oberauer, K., & Hein, L. (2012). Attention to information in working memory. Current Directions in Psychological Science 21, 164-170. doi: 10.1177/0963721412444727

Project Number: 132

Title: Understanding connectivity in the brain: are patterns in baseline activation always driven by neuronal activity?

Supervisor/s: Hannes Saal, Jason Berwick

Location: Pam Liversidge Building, Cathedral Court, Alfred Denny Building

Outline: "Resting state functional Magnetic Resonance imaging (RS-fMRI) research is an emerging field where it is possible to measure functionally connected brain regions at rest. There is evidence that these networks breakdown in neurodegenerative diseases such as Alzheimer's (AD). There is great potential to use RS-fMRI as an early biomarker for AD, however there is a potential confound. fMRI does not measure neuronal activity but a secondary hemodynamic marker. It is also known in diseases such as AD the vascular system is also in decline. Therefore it is possible that RS-fMRI is not mapping neural changes but changes in vascular patterns.

Previous work has shown that respiratory challenges lead to an increase in slow oscillations in the spatiotemporal pattern of blood volume recorded in mouse sensory cortex. This project will analyse high resolution 2D data sets of baseline blood volume oscillations in mouse sensory cortex in the absence of stimulation (similar to RS-fMRI data) before and after a mild respiratory challenge (from breathing oxygen to air).

The aim is to better understand the nature of these spontaneous changes, and specifically to identify more subtle spatial and temporal patterns. Specifically, the student will employ methods from time-series analysis and signal detection to quantify how blood volume spreads cortically, and how this spread is altered in different populations of mice (old age, AD)."

Suitability: This project is ideal for students interested in time-series analysis and, more generally, data science.

Key references:
Hohenfeld et al (2018). Resting-state connectivity in neurodegenerative disorders: Is there potential for an imaging biomarker (2018) – NeuroImage: Clinical 849-870.

Bergonzi et al (2015). Mapping functional connectivity using cerebral blood flow in the mouse brain. Journal of Cerebral Blood flow and Metabolism 35: 367-370.

Ma et al (2016). Resting-state hemodynamics are spatiotemporally coupled to synchronized and symmetric neural activity in excitation neurons. PNAS E8463-E8471.

Project Number: 134

Title: Modelling the impact of deep brain stimulation on the basal ganglia output to the thalamus

Supervisor/s: Robert Schmidt and Mohammad Mohagheghi Nejad

Location: Cathedral Court (collaborator is at the University of Bochum)

Outline: Deep brain stimulation is a common treatment for patients in the advanced stages of Parkinson's disease. One target region in the basal ganglia for this therapeutic stimulation is the basal ganglia output. It has been shown experimentally that the stimulation at the basal ganglia output has diverse effects; a subset of neurons increases their firing rate, another subset decreases, and another subset does not change at all (Hahn et al. 2008). However, how such diverse changes in the firing rate can help to avoid pathological activity in its target thalamic nucleus is poorly understood. Using computational modelling tools, we have recently studied characteristics of the inhibitory basal ganglia outputs to the thalamus that can lead to pathological activity patterns in the thalamus (Nejad et al. 2018). In this project, you will use these computational modelling tools to study the impact of DBS firing rate modulation of the pathological basal ganglia output to a thalamic model neuron. This involves using MATLAB to simulate the thalamic model neuron and its inputs. You can build on available previous implementations, extend these to simulate new scenarios, and write code for analysing the simulation data.

Suitability: Programming and modelling skills (e.g. PSY6307 and PSY6309)

Key references:
Hahn, P. J., Russo, G. S., Hashimoto, T., Miocinovic, S., Xu, W., McIntyre, C. C., & Vitek, J. L. (2008). Pallidal burst activity during therapeutic deep brain stimulation. Experimental neurology, 211(1), 243-251.

Nejad, M. M., Rotter, S., & Schmidt, R. (2018). Transmission of motor signals from the basal ganglia to the thalamus: effect of correlations, sensory responses, and excitation. bioRxiv, 386920.

Project Number: 137

Title: The Relationship between Co-operation and Paranoid Thinking

Supervisor/s: Vyv Huddy

Location: Cathedral Court

Outline: It is well established that paranoid thinking is associated with heightened attribution of malevolent intentions to other people, particularly in ambiguous social scenarios. This finding informs psychological therapies for paranoid and suspicious thinking that causes people distress. There is also some evidence that paranoid thinking is associated with decreased anticipation that others will assist and help in social scenarios. However, it is not clear why this is. One possibility is engaging in co-operation requires reciprocal interactions; there has been very little research on whether paranoid thinking suppresses people's willingness to co-operate with others even when it is of benefit to them. This study will investigate this topic via novel cooperation task that entails computer game format. It will require recruiting a general population sample and use an experimental lab based design.

Suitability: No specific requirements

Key references:
Huddy, V., Brown, G. P., Boyd, T., & Wykes, T. (2014). An exploratory investigation of real-world reasoning in paranoia. Psychology and Psychotherapy: Theory, Research and Practice, 87 (1), 44-59. doi:10.1111/j.2044-8341.2012.02072.x

Lyn Ellett, Rhani Allen-Crooks, Adele Stevens, Tim Wildschut & Paul Chadwick (2013) A paradigm for the study of paranoia in the general population: The Prisoner's Dilemma Game, Cognition and Emotion, 27:1, 53-62, DOI: 10.1080/02699931.2012.689757

Project Number: 140

Title: Relating brain structure to the 2D:4D ratio

Supervisor/s: Dr Iain Croall, Prof Nigel Hoggard

Location: Academic Unit of Radiology, Royal Hallamshire Hospital

Outline: The 2D:4D ratio is the ratio between the length of the second and fourth digits on a person's hand (i.e. the index and ring finger). This ratio has been the focus of study in psychological research for some time as it shows correlations with a number of interesting outcomes from personality traits to incidence of serious psychiatric disorders. The mechanism of these relationships is not fully understood, but is hypothesised to be because the ratio acts as a stand-in marker of testosterone exposure in the womb. Despite this previous psychological research implying a link between brain structure and the 2D:4D ratio, surprisingly few studies have directly examined relationships between the two.
This project will use pre-existing T1-weighted (i.e. structural) MRI scans of healthy volunteers to conduct a series of volumetric analyses, linking together the size of different brain regions to the 2D:4D ratio. The student will gain experience using a number of image processing packages which are popular in clinically-based neuroimaging research (e.g. SPM, FSL).

Suitability: The project should be suitable for a majority of students. The methodological focus will be on image processing and analysis, which will involve work using SPM (which operates from Matlab) and FSL (which operates on a computer running a Linux operating system). Although some coding skills are desirable they are not essential; these are accessible software packages and all work will be achievable using either GUIs or simple instructions to operate a command line. This project should appeal to students with an interest in the physiology of the brain and how this impacts on a variety of outcomes. As the work will take place within a multi-disciplinary team which has a strong clinical focus, it is further suited to someone who is drawn to this setting.

Key references:
A review of the 2D:4D ratio: Jeevanandam S. & Muthu P.K. (2016). 2D:4D Ratio and its Implications in Medicine, J Clin Diagn Res. 10(12), doi: 10.7860/JCDR/2016/21952.9000

The student would be encouraged to do some reading around volumetric analysis methods of T1-weighted MRI scans, for example regional analyses of segmented brain structures, or the global voxel-based morphometry technique.

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The student would be encouraged to do some reading around "volumetric" analysis methods of T1-weighted MRI scans, for example regional analyses of segmented brain structures, or the global "voxel-based morphometry" technique.

Project Number: 144

Title: Temporal expansion of neurovascular coupling by focal cooling

Supervisor/s: Dr Jason Berwick

Location: Alfred Denny Building

Outline: Neurovascular coupling is a homeostatic mechanism that regulates cerebral blood flow in response to increased neuronal activity. As well as providing the active brain with oxygen and glucose it is also the mechanism responsible for generating the signals used in functional magnetic resonance imaging. Neurovascular coupling is also thought to be breaking down in neurodegeneration, especially Alzheimer's disease. Even though we have known about neurovascular coupling for 130 years we still do not know how it works. This project will use focal cooling of the cortex of anaesthetised rats to slow down neurovascular coupling in response to whisker stimulation to allow a more in depth analysis of how neuronal activity drives blood flow. Focal cooling at extremes has also been shown to be a potential treatment for focal cortical epilepsy by inhibiting neuronal activity at the same time as increasing oxygen levels in the brain. Therefore this project will test the same whisker stimulation across a range of temperatures to assess not only neuronal vascular function but also at what temperature is critical for inhibiting baseline neuronal firing at the same time as increasing oxygen supply to the brain.

Suitability: All data has been collected from 6 animals and is awaiting analysis. Matlab analysis is important for the project. However most of the code is generated with GUI's but code development by the student would be encouraged.

Key references:
Harris S, Boorman L, Das D, Kennerley AJ, Sharp PS, Martin C, Redgrave P, Schwartz TH, Berwick J. (2018). Physiological and pathological brain activation in the anesthetized rat produces hemodynamic-dependent cortical temperature increases that can confound the BOLD fMRI signal. Frontiers in Neuroscience 12: 550.

Boorman L, Harris S, Bruyns-Haylett M, Kennerley A, Zheng Y, Martin C, Jones M, Redgrave P, Berwick J (2015). Long-latency reductions in gamma power predict hemodynamic changes that underlies the negative BOLD signal. Journal of Neuroscience 18. 35(11): 4641-4656

Project Number: 145

Title: Explaining tactile distance biases and aftereffects through cortical receptive field structure

Supervisor/s: Hannes Saal, in collaboration with Matthew Longo (Birkbeck, University of London), Elena Azañón (U Magdeburg, Germany)

Location: Pam Liversidge Building

Outline: Our perception of the size of our own body parts is neither accurate nor constant. For example, we perceive our hands as shorter and wider than they actually are. Furthermore, perception of distances on our skin is influenced by prior touches in a systematic fashion. Biases and aftereffects have often been explained with reference to the specific coding and adaptation properties of cortical sensory neurons encoding a certain stimulus, for example in motion and face perception. Can we make a similar link between cortical processing and basic tactile perception in the sense of touch? This project investigates this question using computational modelling. Based on existing psychophysical data, we will investigate whether receptive field structure in somatosensory cortex predicts the observed effects; and if not, which potential receptive field properties would. The project therefore explores a basic link between cortical neural coding and perception.

Suitability: Programming and modelling skills (e.g. based on PSY6308 and PSY6309)

Key references:
Fiori F, Longo MR. Tactile distance illusions reflect a coherent stretch of tactile space. Proceedings of the National Academy of Sciences. 2018; 201715123–201715123.

Calzolari E, Azañón E, Danvers M, Vallar G, Longo MR. Adaptation aftereffects reveal that tactile distance is a basic somatosensory feature. Proceedings of the National Academy of Sciences. 2017;114: 4555–4560."

Project Number: 146

Title: Assessing functional somatotopy during active and passive hand use

Supervisor/s: Hannes Saal and Laura Edmondson, in collaboration with Tamar Makin (UCL) and Daan Wesselink (Oxford)

Location: Pam Liversidge Building

Outline: Modern imaging techniques allow examination of the somatosensory homunculus in unprecedented detail. A lot of attention has been devoted to the representation of the hand, which occupies a large fraction of somatosensory cortex. This region shows activity both during active hand movement, such a wiggling a finger, and during passive stimulation, such as when a finger is touched by a probe. Previous studies often assume that the representation of the hand is the same, whether probed in the active or passive case. Conversely, the differing nature of the inputs (thalamocortical in the passive and intra-cortical in the active case) suggest that cortical representation might differ. Here, we test this idea using an existing data set of detailed activation maps covering primary somatosensory (S1) and motor (M1) cortex collected using a high-field scanner under both active and passive conditions. The student will use typical measures for interrogating somatotopy such as BOLD activation, area sizes, finger distances and RSA to compare the effects of active and passive stimulation.

Suitability: This project is suitable for a student having taken Neuroimaging 1 and 2; willingness to learn some basic programming skills are welcome!

Key references:
Martuzzi, R., van der Zwaag, W., Farthouat, J., Gruetter, R., & Blanke, O. (2014).

Human finger somatotopy in areas 3b, 1, and 2: A 7T fMRI study using a natural stimulus. Human Brain Mapping, 35(1), 213–226. Ejaz N., Hamada M., Diedrichsen J. (2015).

Hand use predicts the structure of representations in sensorimotor cortex. Nat Neurosci. 18. Berlot, E., Prichard, G., O'Reilly, J., Naveed, E., & Diedrichsen, J. (2018).

Ipsilateral finger representations in the sensorimotor cortex are driven by active movement processes, not passive sensory input. Journal of neurophysiology.

Project Number: 147

Title: Markerless tracking of hand kinematics during object grasping and manipulation

Supervisor/s: Hannes Saal

Location: Pam Liversidge Building

Outline: When grasping and manipulating objects we perform a series of stereotyped movements that can be classified into a small set of grasp and exploration types. However, categorisation has relied mostly on manual coding, where videos are coded manually by human observers frame by frame. This method is time-consuming, expensive, and error-prone. To avoid this problem, automated tracking methods have been used, however these often rely on physical markers, sensorized gloves, or other equipment that needs to be attached to a person's hand that might impair their movements and affect results. More recently, markerless tracking methods based on deep learning techniques have been developed that allow precise tracking of individual limbs based on few training frames. This project will adapt an existing framework for markerless tracking to automatically track participants' finger movements as they explore, grasp, and manipulate everyday objects. The resulting data set will be analyzed via hierarchical clustering to reveal major movements types in an unsupervised fashion, without predetermined categories.

Suitability: Familiarity with deep learning models and/or 3D scene reconstruction would be helpful for this project.

Key references:
Mathis A, Mamidanna P, Cury KM, Abe T, Murthy VN, Mathis MW, et al. DeepLabCut: markerless pose estimation of user-defined body parts with deep learning. Nat Neurosci. 2018;21: 1281–1289.

Lederman SJ, Klatzky RL. Hand movments: A window into haptic object recognition. Cogn Psychol. 1987;19: 342–368.

MSc Systems Neuroscience Projects

Project Number: 101

Title: BYOM - Bring Your Own Model!

Supervisor/s: Hannes Saal, Stuart Wilson, Robert Schmidt

Location: Cathedral Court / Pam Liversidge Building

Outline: You already have an exciting idea for a computational model that you would like to investigate for your dissertation project? Is that idea more specific than just e.g. ‘modelling memory’ or ‘modelling the basal ganglia’? If so, then we are happy to discuss your idea in more detail to see whether it can be turned into a dissertation project. We would expect that you present your model idea in a 1-page written summary, and explain how you will use the model to answer a specific research question. Ideally, your model should be based on a published model in the scientific literature and you should be able to implement it with your current programming skills. The topic should address a current research area of computational neuroscience.

Suitability: Programming and modelling skills (e.g. based on PSY6307 and PSY6309)

Key references: N/A

Project Number: 102

Title: Big data on learning

Supervisor/s: Tom Stafford

Location: Flexible

Outline: I (Tom) have access to large existing data sets which contain the potential to show skill development on real-world tasks for large numbers of people (i.e. n>1,000,000 in domains of chess and online video games). Using theory from the cognitive science of learning and advanced statistical models and/or data visualisation techniques we will test theories of what makes learning most effective. Can we look at how people practice and relate this to the level of skill they reach? The ambition will be to design more effective learning practices. You will have an opportunity to work with the theory of the psychology of learning and a skill set encompassing state-of-the-art open-source analytics tools.

Suitability: Knowledge of R or Python or a strong willingness to learn these

Key references:
Stafford, T. & Haasnoot, E. (2017). Testing sleep consolidation in skill learning: a field study using an online game. Topics in Cognitive Science. 9(2), 485-496.

Project Number: 103

Title: Microsaccades and ADHD/ASD

Supervisor/s: Tom Stafford

Location: Mushroom Lane & Cathedral Court

Outline: Attention Deficit Hyperactivity Disorder (ADHD) is the most prevalent neurodevelopmental disorder, however the neural changes that underlie the disorder are poorly understood. Recent evidence suggests that a midbrain structure, the superior colliculus, is an important dysfunctional locus in the disorder. The superior colliculus plays a central role in the generation of eye movements, amongst them microsaccades (small amplitude saccades made during fixation), and we have recently shown that microsaccade rate positively correlates with ADHD-type symptoms in a non-clinical adult population, suggestive of a 'hyper-active' colliculus (Panagiotidi et al., 2017). The project we envisage will develop testing of whether it is possible to track changes in microsaccade rate over time in individual participants (Hampsey et al, submitted). In particular, we would like to see if response to caffeinated drinks affects microsaccade rate. Caffeine is a dopamine agonist, and dopamine plays an important functional role in both attention and collicular function). If it is possible to measure the time-response function using microsaccades then this is an important proof-of-concept for testing and developing pharmacotherapies in ADHD which are based on the collulicar hypersensitive hypothesis.

Suitability: Technical aptitude (eye-tracking) and experimental design skills required

Key references: Panagiotidi, M., Overton, P.G., Stafford, T. (2017). Increased microsaccade rate in individuals with ADHD traits. Journal of Eye Movement Research. 10,1
Hampsey, E., Overton, P.G., Stafford, T. (submitted). Microsaccade rate as a measure of drug response. https://psyarxiv.com/r6duk

Project Number: 104

Title: Cognitive Mapping versus Associative accounts of spatial learning in Virtual Reality

Supervisor/s: Stuart Wilson

Location: Pam Liversidge (experiments will take place in the VR lab in the Mappin Mining Block)

Outline: Is spatial learning distinct from other forms of learning? According to associative learning theories, when we encounter new information, whether temporal or spatial, that information is processed according to the same associative mechanisms. In contrast, according to cognitive mapping theory, when we explore a new environment we automatically construct a representation of that environment in which all distinctive landmarks, together with the geometric relationships between those landmarks, are stored. A mental representation of the environment in this structure can be employed to solve novel spatial problems. As such, the mechanisms that underpin spatial learning are presumed to be distinct from those that underpin non-spatial learning Cognitive mapping and associative learning theories make a number of different predictions about the way in which humans and other animals learn about space. For example, associative learning theories predict cue-interaction effects, such as blocking and overshadowing, whereas cognitive mapping theory does not, and cognitive mapping theory predicts that animals can automatically compute novel short-cut routes whereas associative learning does not. The aim of this project is to test the predictions of these two theories, by reproducing experimental designs in either cue-competition or short-cutting that have been well established in the classic animal learning literature, using human participants navigating environments experienced via Virtual Reality. See Alexander, Wilson, Wilson (2009) and Wilson & Wilson (2018 - in press) for examples of studies in this area.

Suitability: This project will involve the design and creation of new Virtual Environments using Unity 3D software. You will recruit participants, collect data in the Sheffield Robotics / INSIGNEO Virtual Reality and Motion Capture Lab in the Mappin Mining Block, and you will perform statistical analyses to test for short-cutting and/or cue-competition. This project is well suited to an experimental psychologist with an interest in computer-aided design or computer gaming. Students with ideas for constructing computational models of spatial learning to explain the existing data are also welcome to apply.

Key references:

O'Keefe J, Nadel L. The hippocampus as a cognitive map. Oxford University Press: Oxford; 1978.

Alexander T, Wilson SP, Wilson PN. (2009) Blocking of spatial learning based on shape. Journal of Experimental Psychology: Learning, Memory, and Cognition, 35(3):694–708.

Olton DS. (1978) Mazes, maps, and memory. American Psychologist, 34(7):583–596.

Pearce JM. (2009) The 36th Sir Frederick Bartlett Lecture: An associative analysis of spatial learning. The Quarterly Journal of Experimental Psychology, 62(9):1665–1684.

Wilson SP, Wilson PN (2018) Failure to demonstrate short-cutting in a replication and extension of

Tolman et al.'s spatial learning experiment with humans. PLoS ONE X(Y): e0208794.

Project Number: 105

Title: Telepresence immersion in an animal-like robot

Supervisor/s: Stuart Wilson Tony Prescott (Computer Science and Sheffield Robotics)

Location: Pam Liversidge Building

Outline: We work as part of Sheffield Robotics on biomimetic robotics, with a particular focus on brain-inspired computing, active sensing, scene understanding, episodic and spatial memory, social cognition and human-robot interaction. We are interested in the use of robots as telepresence devices for remote action in work and entertainment settings, and have created various telepresence interfaces for physical robots using virtual reality head-sets and different forms of body tracking (see Martinez-Hernandez et al., 2017). This project would explore whether we can give people a convincing immersive experience in a non-humanoid robot using the MiRo animal-like robot. As well as developing the telepresence system projects could explore its psychological impact. What is the experience of being immersed in a non-humanoid robot? Are there after-effects?

Suitability: Students should have reasonable programming skills (ideally Python or C++) and an interest in societal applications of robotics. Some knowledge of psychology and/or experimental design would be useful. No prior familiarity with robots in needed.

Key references:

Martinez-Hernandez, U., Boorman, L. W. and Prescott, T. J. (2017). Multisensory Wearable Interface for Immersion and Telepresence in Robotics. IEEE Sensors Journal, 17(8), 2534-2541. doi:10.1109/JSEN.2017.2669038

Mitchinson, B. and Prescott, T. J. (2016). MIRO: A Robot Mammal with a Biomimetic Brain-Based Control System. Living Machines V: Biomimetic and Biohybrid Systems, LNCAI 9793, pp. 179-191.

Project Number: 107

Title: Reaction-diffusion modelling of cortical arealization

Supervisor/s: Stuart Wilson and Sebastian James

Location: Pam Liversidge Building

Outline: Morphogenesis (pattern formation) in biological systems can be understood in terms of the tension between local excitatory interactions between cells and longer-ranging inhibitory interactions. Reaction-diffusion models, based on the ideas of Alan Turing, provide a formalism for understanding how this tension can lead to different patterns, e.g., resulting in the stripes versus spots of colour we see on animal skins. Similar processes describe how patterning in the brain occurs, in particular in the developing neocortex. The aim of this project is to investigate how genetic constraints acting on reaction-diffusion processes shape the patterning of the developing neocortex to result in differences in the relative size and shape of the primary cortical areas (A1, V1, S1 etc.). The two papers below by Bard Ermentrout outline a) a reaction-diffusion approach to between-area patterning in a 1D model of cortical development, and b) a reaction-diffusion approach to within-area patterning in a 2D model of cortical development. We have been combining these two approaches to create a reaction-diffusion model with which to investigate between-area pattern formation on a simulated 2D cortical sheet. The aim of this project is to calibrate the model to data obtained by our collaborator lab at University California Davis (Leah Krubitzer), who have been experimentally manipulating the size of the cortical sheet and the sensory experiences of developing animals across a range of mammalian species

Suitability: The mathematics (partial differential equations) and computing (c++ and python) foundations of this project are now fairly well established, and as such projects can be designed around the mathematical/computing expertise and interests of the student.

Key references:

Karbowski, Ermentrout (2004) Model of the Early Development of Thalamo-Cortical Connections and Area Patterning via Signaling Molecules. Journal of Computational Neuroscience 17, 347–363

Ermentrout B, Simons DJ, Land PW (2009) Subbarrel Patterns in Somatosensory Cortical Barrels Can Emerge from Local Dynamic Instabilities. PLoS Computational Biology 5(10): e1000537

Krubitzer, Dooley (2013) Cortical plasticity within and across lifetimes: how can development inform us about phenotypic transformations? Frontiers in Human Neuroscience, 7 (620), 1-14.

Project Number: 108

Title: Artificial gene regulatory networks

Supervisor/s: Stuart Wilson and Daniel Whiteley

Location: Pam Liversidge Building

Outline: We have been using principles from Artificial Neural Networks research to construct models of how gene-regulatory networks evolve and develop. Specifically, we are interested in the networks that give rise to the graded patterns of gene expression that guide development of thalamocortical axons and ultimately specify the primary cortical fields (V1, S1, A1 etc.). In this project we will investigate how constraints on the network architecture (e.g., feed-forward versus fully connected recurrent networks) might account for the range of gene expression patterns observed in real gene networks, using a new technique we have been developing for disabling network learning to represent the effects of gene knock-out experiments. Depending on student interest, there is also scope for exploring these problems further using evolutionary algorithms.

Suitability: The focus of this project can be shifted depending on the expertise/interests of the student either to focus on algorithm development on the reasonably small-scale, or to run more intensive simulations. Willingness to learn c++ and/or python is required.

Key references:

Giacomantonio CE, Goodhill GJ (2010) A Boolean Model of the Gene Regulatory Network Underlying Mammalian Cortical Area Development. PLoS Computational Biology 6(9): e1000936.

Kauffman, S. (1995). At home in the universe: The search for laws of complexity. London: Penguin Books.

Hinton & Nolan (1987) How learning can guide evolution. Complex Systems 1: 495-502.

Greig et al., (2013) Molecular logic of neocortical projection neuron specification, development and diversity. Nature Neuroscience Reviews, 14: 755.

Project Number: 109

Title: Modelling thermoregulatory huddling

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Rodents are a very important model in developmental neuroscience. Current attempts to simulate e.g., rat brain development often neglect the fact that rat brains develop in rat bodies to help them to do ratty things! One of the most important ratty things is huddling with littermates to keep warm. In the first postnatal weeks when the cortex is wiring itself up, huddling is perhaps the most important source of correlation between sensory modalities. For example, turning to huddle with a warm littermate on the right provides a leftward optic flow that is correlated with tactile input to the right of the body, an increase in thermal reward, and increases in the sounds and smells emitted by the littermate etc. The aim of this project is to develop a simulation of a virtual rat litter, in order to synthesize these patterns of multisensory correlation under different huddling conditions (i.e., at different temperatures), and to explore how different huddling conditions affect simulated brain development. The idea is to investigate whether self-organising models of cortical map development (see Bednar and Wilson, 2015 for a primer) can learn to exploit these correlations to make better huddlers.

Suitability: This project will be fun for students who can program, at least in python (and preferably in c++).

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Glancy J, Gross R, Stone JV, Wilson SP (2015) A self-organising model of thermoregulatory huddling. PLoS Computational Biology 11(9): e1004283. doi:10.1371/journal.pcbi.1004283

Wilson SP. (2017) Modelling the emergence of rodent filial huddling from physiological huddling. Royal Society Open Science, 4: 170885.

Project Number: 110

Title: The effect of cortical boundary shape on the emergence of cortical feature maps

Supervisor/s: Stuart Wilson

Location: Pam Liversidge Building

Outline: Stimulus-driven self-organisation represents the current best theory of the emergence of cortical feature maps. Continuous maps of visual orientation preference that match essentially all existing data on biological maps can be reproduced by computational models such as LISSOM and GCAL (Stevens et al., 2013) that represent Hebbian learning, short-range excitatory interactions and long-range inhibitory interactions between neurons on a cortical sheet. We have been developing software that allows these algorithms to be simulated on cortical sheets with arbitrary boundary shapes. The aim of this project is to investigate whether such models can also account for the alignment of orientation preference map structure with the boundary shape (iso-orientation contours tend to intersect the boundary at right angles).

Suitability: This project is suited to students with a willingness to learn to programme in c++ and python.

Key references:

Bednar, J. A. and Wilson, S. P. (2015), Cortical Maps. The Neuroscientist, 10.1177/1073858415597645

Stevens JLR, Law JS, Antolʹık J, Bednar JA. Mechanisms for stable, robust, and adaptive development of orientation maps in the primary visual cortex. The Journal of Neuroscience. 2013; 33(40):15747– 15766.

Wilson SP, Bednar JA. What, if anything, are topological maps for? Developmental Neurobiology. 2015; 75(6):667–681.

Project Number: 111

Title: A comparison of EEG signal complexity measures

Supervisor/s: Dr Myles Jones

Location: Cathedral Court

Outline: Complexity of resting state and stimulus evoked EEG signals has been shown to differ in neurodevelopmental conditions such as Autism (Milne et al., 2019). However, there are many ways to estimate the complexity of a signal (see Parameshwaran et al., 2019) with Parameshwaran et al., (2019) suggesting a novel metric ('waveform complexity') provides superior correlations to task performance than other measures. As such the current investigation seeks to examine which of the different metrics outlined in Parameshwaran et al., (2019) display greater differences in previously collected EEG data from those with Autistic Spectrum Conditions compared to control subjects (Milne et al., 2019).

Suitability: No specific requirements

Key references:
Milne, E., Gomez, R., Giannadou, A., & Jones, M. (2019). Atypical EEG in autism spectrum disorder: Comparing a dimensional and a categorical approach. Journal of Abnormal Psychology, 128(5), 442-452. doi:10.1037/abn0000436

Parameshwaran, D., Subramaniyam, N. P., & Thiagarajan, T. C. (2019). Waveform complexity: A new metric for EEG analysis. J Neurosci Methods, 325, 108313. doi:10.1016/j.jneumeth.2019.108313

Project Number: 112

Title: Effects of systemic inflammation on brain vascular function

Supervisor/s: Chris Martin

Location: Alfred Denny Labs and Cathedral Court

Outline: The regulation of blood flow in the brain according to the metabolic demands of active brain cells is a subject of great importance for two research areas: (i) the understanding of functional brain imaging data; (ii) the role of altered blood flow regulation in a range of neurodegenerative and neuropsychiatric diseases. In Sheffield we use a range of in-vivo methods in animal models (including imaging and electrophysiology) to study brain blood flow regulation in detail. There are a number of specific questions being asked in the lab that can form the basis of an MSc project, including: (i) how does systemic inflammation (an immune response to injury or illness) affect brain blood flow regulation; (ii) how do alterations in brain serotonin function (as implicated in affective/mood disorders) affect blood flow regulation; (ii) how do alterations in the function of other major neuromodulatory neurotransmitter systems (dopamine, acetylcholine) affect brain blood flow regulation. There are a range of specific hypotheses that can be tested for each project area.

Suitability: Experience of, or willingness to learn to use MatLab for data analysis would be useful. Projects can be tailored for either students with more advanced computational/analysis/modelling skills, or for those who wish to focus in more detail on neurobiological issues. Getting hands on experience of animal work is restricted due to Home Office (legal) regulations, but students will be able to spend time in the lab and become familiar with the environment, methods and procedures.

Key references:

Spain, Aisling, et al. Neurovascular and neuroimaging effects of the hallucinogenic serotonin receptor agonist psilocin in the rat brain. Neuropharmacology 99 (2015): 210-220. [describe some of the key methodology and approach used in the lab]

Brezzo, Gaia, et al. Acute effects of systemic inflammation upon neurovascular unit and cerebrovascular function. bioRxiv (2018): 498089.

Jeon, Sang Won, and Yong-Ku Kim. The role of neuroinflammation and neurovascular dysfunction in major depressive disorder. Journal of inflammation research 11 (2018): 179. [optional, skip to the neurovascular sections]

Project Number: 113

Title: Neurovascular coupling and aging

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: The brain is energetically expensive, accounting for only 2% of the body's mass, it uses 20% of the body's resting energy. In order to maintain normal brain function, it is essential that neuronal energy demands are met by changes in local blood flow. This matching of energy supply and demand is accomplished through a mechanism termed neurovascular coupling. The changes in blood flow associated with neural activity are the basis of functional imaging signals such as BOLD fMRI.
Evidence suggests that neurovascular coupling is dysfunctional in both aging and neurodegenerative diseases (e.g. Alzheimer's disease). Such changes in neurovascular function could contribute to cognitive decline which is associated with aging. This project will analyse an existing dataset in order to elucidate further the changes which occur in neurovascular function during aging. Data collection involved multimodal techniques (e.g. 2D-Optical Imaging Spectroscopy to measure haemodynamic changes, multi-channel electrophysiology to concurrently measure neural activity) in mice of different ages (6-24 months old). Students may view data collection if they wish.

This research will (1) increase our understanding of normal brain function, (2) elucidate neurovascular dysfunctions which occur in aging, (3) increase our ability to accurately interpret functional imaging signals and (4) reveal potential therapeutic loci for neurodegenerative diseases.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Attwell et al., 2010 Nature 468

Aanerud et al., 2012 JCBFM 32

farkas & Luiten, 2001 Prog Neurobiol. 64

Girouard & Iadecola, 2006 J Appl Physiol. 100

Project Number: 114

Title: Using optogenetics to investigate the role of cortical interneurons in neurovascular coupling.

Supervisor/s: Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a vital brain mechanism ensuring that neuronal energy demands are met by dynamic changes in local blood flow. This mechanism underlies functional neuroimaging techniques such as BOLD fMRI and may be dysfunctional in neurodegenerative diseases.
We have previously combined a cell-specific optogenetic approach with 2-dimensional optical imaging spectroscopy (2D-OIS) and electrophysiology in anaesthetized mice to demonstrate that specific activation of single populations of cortical interneurons (those expressing somatostatin [SST] or neuronal nitric oxide synthase [nNOS]) is sufficient to elicit robust haemodynamic responses. Furthermore we have demonstrated that, in the case of nNOS-expressing interneurons, this increase in blood volume occurs in the absence of a large change in neuronal activity.
By further understanding the influence of these cells on normal network physiology and haemodynamic correlates we can not only begin to decipher how interneurons may contribute to disease processes but also improve our ability to interpret perfusion-based neuroimaging signals.
This project will involve analysis of existing datasets, using MATLAB. Students may view data collection if they wish.

Suitability: It would be useful for the student to have some MATLAB skills/experience for this project.

Key references:
Cauli B., et al. (2004) J. Neurosci. 24: 8940-9

Cauli B. & Hamel E. (2010) Front. Neuroenergetics 2: 9

Lee et al. (BiorXiv) https://doi.org/10.1101/550269

Uhlirova H., et al. (2016) Elife 5: e14315

Anenberg E., et al. (2015) J Cereb Blood Flow Metab 35: 1579-1586

Project Number: 115

Title: Trial-to-trial variability in human EEG recordings during visual stimulation and behaviour

Supervisor/s: Robert Schmidt and Elizabeth Milne

Location: Cathedral Court

Outline: In this project you will analyse EEG data recorded in humans performing a simple behavioural task. In the task a visual checkerboard stimulus was presented to the participants, who then had to respond to the offset of the stimulus with a button press. To what degree does neural activity reflect different aspects of the task? To address this you will apply several basic EEG analysis methods such as time-frequency analysis using spectrograms. Furthermore, you will examine neural variability, e.g. in the context of how neural oscillations before a trial affect the neural responses to the visual stimulus. The goal is to identify neural variability that correlates with behavioural variability (i.e. reaction times; how quickly the participants pressed the button). The project is suited for a student interested in the analysis and visualisation of large data sets (in this case many, recording channels, experimental trials and participants).

Suitability: Programming and data analysis skills (e.g. based on PSY6309)

Key references:

Becker, R., Ritter, P., & Villringer, A. (2008). Influence of ongoing alpha rhythm on the visual evoked potential. Neuroimage, 39(2), 707-716.

Leventhal, D. K., Gage, G. J., Schmidt, R., Pettibone, J. R., Case, A. C., & Berke, J. D. (2012). Basal ganglia beta oscillations accompany cue utilization. Neuron, 73(3), 523-536.

Makeig, S., Delorme, A., Westerfield, M., Jung, T. P., Townsend, J., Courchesne, E., & Sejnowski, T. J. (2004). Electroencephalographic brain dynamics following manually responded visual targets. PLoS biology, 2(6), e176.

Project Number: 116

Title: Design your own fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: You can soley, or as a part of a group, come up with an experimental question that you would like to investigate using fMRI. This can be an original idea, or a study that aims to extend or solely validate/replicate a previous study. You will be responsible for designing the task, piloting it, acquiring and analyzing the fMRI data. Any questions please get in touch.

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Amaro, E., Jr. & Barker, G. J. Study design in fMRI: basic principles. Brain Cogn, 2006, 60, 220-232

Project Number: 117

Title: Effect of negative and positive social feedback – An fMRI study

Supervisor/s: Liat Levita

Location: Cathedral Court

Outline: This fMRI study has been designed to examine the effect and neural substrates of how we react to individuals that have been associated with either positive and negative outcomes or social feedback. The aim is to understand how such events shape/bias our emotional and decision making responses to different individuals, and the brain regions involved. You will get invaluable training and insight of fMRI experimental design and analysis methodologies. In this study you will develop the experimental paradigm, and acquire fMRI data from adult participants. The aim is to work as a group on these aspects, and once the data has been acquired, work individually to analyse the fMRI data on the questions that interest you. Any questions please get in touch

Suitability: Prerequisites –PSY6414 Neuroimaging 1

Key references:
Wiggert, N., Wilhelm, F. H., Boger, S., Georgii, C., Klimesch, W., & Blechert, J. (2017). Social Pavlovian conditioning: Short- and long-term effects and the role of anxiety and depressive symptoms. Social Cognitive and Affective Neuroscience, 12(2), 329-339. doi:10.1093/scan/nsw128

Project Number: 118

Title: An examination of parvalbumin expressing interneurons in murine models of autism spectrum disorder.

Supervisor/s: Dr Timothy Riley; Dr Martin Clark (external collaborator)

Location: Alfred Denny; Cathedral Court

Outline: Emerging evidence suggests that altered interneuron levels may underpin the behavioral deficits that are central to the symptoms of autism spectrum disorder (ASD). Specifically, it has been suggested that one of genetic networks that is associated with ASD may code for a downregulation of parvalbumin (PV) expressing interneurons in the basal ganglia. Recent evidence utilising PV knockout mouse models (mice that have been genetically modified to express limited levels of PV interneurons), shows that these mice display the core behavioural symptoms present in human ASD. Further, electrophysiological evidence in this model suggests that these symptoms may present in part due to altered synaptic transmission resulting from downregulated PV expression. Thus while it has been shown that altered PV expression is associated with ASD like symptoms, it has yet to be established if ASD-like symptoms are associated with altered PV expression. The proposed study would aim to expand previous findings to consider if PV interneuron expression is altered in validated mouse models of ASD, focusing on differences in the expression profiles of PV interneurons in the dorsal striatum and, potentially, other regions of the basal ganglia. This project will utilise an ex-vivo immunohistochemistry methodology; students working on this project, will slice, stain, and examine the brains of mouse models of ASD under supervision.

Suitability: This project is best suited for students with an interest in systems neuroscience who want to gain firsthand experience of lab work.

Key references:

Wöhr, M., Orduz, D., Gregory, P., Moreno, H., Khan, U., Vörckel, K. J., Schwaller, B. (2015). Lack of parvalbumin in mice leads to behavioral deficits relevant to all human autism core symptoms and related neural morphofunctional abnormalities. Translational Psychiatry, 5, e525. doi:10.1038/tp.2015.19

Fuccillo, M. V. (2016). Striatal Circuits as a Common Node for Autism Pathophysiology. Frontiers in Neuroscience, 10, 27.

Garas, F. N., Shah, R. S., Kormann, E., Doig, N. M., Vinciati, F., Nakamura, K. C., Sharott, A. (2016). Secretagogin expression delineates functionally-specialized populations of striatal parvalbumin-containing interneurons. eLife, 5. doi:10.7554/eLife.16088

Project Number: 119

Title: Neurovascular breakdown in Dementia and Atherosclerosis

Supervisor/s: Dr Jason Berwick, Dr Clare Howarth

Location: Alfred Denny Building

Outline: Neurovascular coupling is a homeostatic mechanism that is responsible for increasing cerebral blood flow in response to neuronal activity to ensure the brain is supplied with enough oxygen and glucose to function properly. A new idea called the neurovascular degeneration hypothesis suggests a breakdown in neurovascular coupling is an important factor in neurodegenerative diseases, especially Alzheimer's. Our laboratory has been investigating neurovascular breakdown in a transgenic Alzheimer's mice for a number of years. To date our findings actually show that neurovascular coupling is preserved in the model (J20) we use, against other findings in the field. However, recently we have developed a new model in which we give our J20 mouse an induced form of Atherosclerosis. In this model neurovascular coupling appears to be significantly affected. New data is currently being collected and will be analysed as part of this project.

Suitability: The students will observe data collection and will then use Matlab to analyse the results. Having the ability to write and edit code would be beneficial to the project. However, most core code already exists for data analysis

Key references:

Ameen-Ali K, Simpson JE, Wharton SB, Heath PR, Sharp P, Brezzo G, Berwick J (2019) The time course of recognition memory impairment and glial pathology in the hAPP-J20 mouse model of Alzheimer's disease. Journal of Alzheimer’s Disease 68(2):609-624.

Shabir O, Berwick J, Francis SE. (2018) Neurovascular dysfunction in vascular dementia, Alzheimer’s and atherosclerosis. BMC Neuroscience 19:62.

Ameen-Ali KE, Wharton SB, Simpson JE, Heath PR, Sharp P, Berwick J (2017). Review: Neuropathology and behavioural features of transgenic murine models of Alzheimer's disease. Neuropathology and Applied Neurobiology 43: 553-570.

Sharp PS, Shaw K, Boorman L, Harris S, Kennerley AJ, Azzouz M, Berwick J. (2015). Comparison of stimulus-evoked cerebral hemodynamics in the awake mouse and under a novel anesthetic regime. Scientific Reports 12621 doi:10.1038/srep12621.

Project Number: 128

Title: Modelling the effect of emotional and drug-related cues on response inhibition

Supervisor/s: Robert Schmidt and Matt Field

Location: Cathedral Court

Outline: How does our brain make decisions? Many aspects of decision-making, including response inhibition, have successfully been modelled using a simple description of accumulating processes growing towards a threshold. For example, two different processes might represent two different choices, and the process that reaches the threshold first is chosen. The time that the process took to reach the threshold can then be used to model reaction times. This has been used to describe behaviour and neural activity in a stop-signal task, in which a "Go" process races against a "Stop" process. In this project the student develops a novel computational model describing action suppression in the context of emotional and alcohol-related cues (Jones and Field, 2015). To do so the student will first implement a horse race model of stopping (e.g. Boucher et al., 2007) and then devise a new way to incorporate different types of stimuli (i.e. emotional and drug-related cues) and investigate their effect on inhibitory control. The results are relevant both for computational models of decision-making circuits and the neural basis of drug abuse.

Suitability: Programming and modelling skills (e.g. based on PSY6307, PSY6309)

Key references:
Boucher, L., Palmeri, T. J., Logan, G. D., & Schall, J. D. (2007). Inhibitory control in mind and brain: an interactive race model of countermanding saccades. Psychological Review, 114(2), 376.

Jones, A., & Field, M. (2015). Alcohol-related and negatively valenced cues increase motor and oculomotor disinhibition in social drinkers. Experimental and clinical psychopharmacology, 23(2), 122.

Schmidt, R., Leventhal, D. K., Mallet, N., Chen, F., & Berke, J. D. (2013). Canceling actions involves a race between basal ganglia pathways. Nature Neuroscience, 16(8), 1118-1124.

Project Number: 142

Title: Caffeine and ADHD-like traits

Supervisor/s: Paul G. Overton

Location: Various

Outline: Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common neurodevelopmental disorders, the symptoms of which continue into adulthood in as many as 43% of individuals. The disorder is characterised by the triumvirate of hyperactivity, impulsivity and attentional problems, and it's causes at the neural level are largely unknown. However, a few years ago we made the novel proposal that the core attentional symptom of increased distractibility is due to the dysfunction of the superior colliculus - a sensory structure in the midbrain (Overton, 2008). In particular, we proposed that the colliculus is hyper-responsive to sensory stimuli in ADHD. Recent evidence from our group suggests that caffeine is able to depress collicular function, suggesting that this common drug may have an as-yet-unrealised therapeutic role to play in ADHD. The envisaged project will test this possibility by examining the effect of caffeine on reaction time performance in a task involving distractors, and examine the impact of the drug on performance (distractibility) in adult non-clinical participants with high and low levels of ADHD-like traits.

Suitability: No specific requirements

Key references:
Overton PG. Collicular dysfunction in attention deficit hyperactivity disorder. Med Hypotheses. 2008;70(6):1121-7.

Project Number: 144

Title: Temporal expansion of neurovascular coupling by focal cooling

Supervisor/s: Dr Jason Berwick

Location: Alfred Denny Building

Outline: Neurovascular coupling is a homeostatic mechanism that regulates cerebral blood flow in response to increased neuronal activity. As well as providing the active brain with oxygen and glucose it is also the mechanism responsible for generating the signals used in functional magnetic resonance imaging. Neurovascular coupling is also thought to be breaking down in neurodegeneration, especially Alzheimer's disease. Even though we have known about neurovascular coupling for 130 years we still do not know how it works. This project will use focal cooling of the cortex of anaesthetised rats to slow down neurovascular coupling in response to whisker stimulation to allow a more in depth analysis of how neuronal activity drives blood flow. Focal cooling at extremes has also been shown to be a potential treatment for focal cortical epilepsy by inhibiting neuronal activity at the same time as increasing oxygen levels in the brain. Therefore this project will test the same whisker stimulation across a range of temperatures to assess not only neuronal vascular function but also at what temperature is critical for inhibiting baseline neuronal firing at the same time as increasing oxygen supply to the brain.

Suitability: All data has been collected from 6 animals and is awaiting analysis. Matlab analysis is important for the project. However most of the code is generated with GUI's but code development by the student would be encouraged.

Key references:
Harris S, Boorman L, Das D, Kennerley AJ, Sharp PS, Martin C, Redgrave P, Schwartz TH, Berwick J. (2018). Physiological and pathological brain activation in the anesthetized rat produces hemodynamic-dependent cortical temperature increases that can confound the BOLD fMRI signal. Frontiers in Neuroscience 12: 550.

Boorman L, Harris S, Bruyns-Haylett M, Kennerley A, Zheng Y, Martin C, Jones M, Redgrave P, Berwick J (2015). Long-latency reductions in gamma power predict hemodynamic changes that underlies the negative BOLD signal. Journal of Neuroscience 18. 35(11): 4641-4656

Project Number: 146

Title: Assessing functional somatotopy during active and passive hand use

Supervisor/s: Hannes Saal and Laura Edmondson, in collaboration with Tamar Makin (UCL) and Daan Wesselink (Oxford)

Location: Pam Liversidge Building

Outline: Modern imaging techniques allow examination of the somatosensory homunculus in unprecedented detail. A lot of attention has been devoted to the representation of the hand, which occupies a large fraction of somatosensory cortex. This region shows activity both during active hand movement, such a wiggling a finger, and during passive stimulation, such as when a finger is touched by a probe. Previous studies often assume that the representation of the hand is the same, whether probed in the active or passive case. Conversely, the differing nature of the inputs (thalamocortical in the passive and intra-cortical in the active case) suggest that cortical representation might differ. Here, we test this idea using an existing data set of detailed activation maps covering primary somatosensory (S1) and motor (M1) cortex collected using a high-field scanner under both active and passive conditions. The student will use typical measures for interrogating somatotopy such as BOLD activation, area sizes, finger distances and RSA to compare the effects of active and passive stimulation.

Suitability: This project is suitable for a student having taken Neuroimaging 1 and 2; willingness to learn some basic programming skills are welcome!

Key references:
Martuzzi, R., van der Zwaag, W., Farthouat, J., Gruetter, R., & Blanke, O. (2014).

Human finger somatotopy in areas 3b, 1, and 2: A 7T fMRI study using a natural stimulus. Human Brain Mapping, 35(1), 213–226. Ejaz N., Hamada M., Diedrichsen J. (2015).

Hand use predicts the structure of representations in sensorimotor cortex. Nat Neurosci. 18. Berlot, E., Prichard, G., O'Reilly, J., Naveed, E., & Diedrichsen, J. (2018).

Ipsilateral finger representations in the sensorimotor cortex are driven by active movement processes, not passive sensory input. Journal of neurophysiology.