Topics for placement and project work in MSc Cognitive Neuroscience and Neuroimaging

Members of Academic Staff in the School of Psychology and other departments contributing to the lecture program would be willing to supervise research in the areas listed below (sorted alphabetically by supervisor's last name). **All projects are subject to confirmation by supervisors;** for email addresses see http://www.nottingham.ac.uk/psychology/people/index.php

Please note: this list is preliminary and may be updated during the next few weeks. For students registered on an MSc/PhD programme, the PhD supervisor will offer placement and project. Students registered on the "stand-alone" MSc 1-year programme may want to choose a topic of interest from the list below and then contact the respective member of Academic Staff.

Dr Sygal AMITAY (MRC Institute of Hearing Research, Auditory Learning Group) HOW TO IMPROVE YOUR HEARING: AUDITORY TRAINING EFFECTS ON PSYCHOPHYSICAL TUNING CURVES

Auditory training can work like sports training – if you practice a listening task you get better at it. Training can induce long-lasting changes in performance on almost all auditory tasks. We have previously shown (e.g. Amitay et al., 2006) that high-level cognitive skills such as attention play a crucial role in learning even a simple auditory discrimination. However, the extent to which bottom-up processes contribute to learning is still unclear. In this project we propose to investigate whether training in auditory frequency discrimination changes the shape of the auditory filter. We predict that an improvement in frequency discrimination will be accompanied by a narrowing of the psychophysical tuning curve (PTC) for frequency, reflecting changes in the shape of the auditory filter. We will measure the width of the auditory filter before and after training using psychoacoustic techniques, and correlate it with the improvement in frequency discrimination.

Amitay, S., Irwin, A. & Moore, D.R. (2006) Discrimination learning induced by training with identical stimuli. Nature Neuroscience, 9, 1446-1448.

Dr Henry CHASE and Dr Lee HOGARTH (School of Psychology)

The concept of prediction error is central to associative learning models (e.g. Rescorla and Wagner, 1972) and has been integral for the understanding of reward- and punishment-related neural activity (e.g. Schultz, 2006). An event related potential (ERP) called the feedback-related negativity (FRN) has been associated with negative prediction errors (Holroyd and Coles, 2002) i.e. when the obtained outcome is worse than expected.

This ERP has been intensively studied: however, it remains unclear exactly what psychological aspect of negative prediction error it represents. Two aspects may be distinguished: surprise and updating. The first, surprise, is the psychological consequence of an unpredicted event, leading to behavioural effects such as increases in attentional orienting. The second, updating, reflects the fact that prediction errors are used to modulate the strength of associations between stimuli.

In typical neuroscientific experiments, no attempt is made to distinguish these two possibilities. However, by exploiting the learning set phenomenon – in which learning performance improves with successive learning problems – it is possible to modulate learning rate and hence the relative contribution of surprise and updating following a given feedback event. Specifically, as learning rate increases, updating of associations is faster but surprise decreases. Consequently, if the FRN is associated with updating, it should be larger with successive discrimination problems, whereas if it is associated with surprise, it should get progressively smaller.

This study may be also relevant for understanding addiction, as a related waveform, the error-related negativity (ERN) is reduced in addicted patient groups (e.g. Franken et al., 2007). It is also reduced in impulsive subjects (e.g. Martin, Potts and others. 2006/2008): impulsivity being a risk factor for addiction. Two groups of subjects would be recruited for the present study: daily cigarette users (who have made the transition into drug dependence) and non-daily cigarette users (who have not), and FRN amplitudes will be compared between the two groups. I you would like any further information about the study, please contact Henry Chase (lpzhwnc@nottingham.ac.uk).

Dr Lucy CRAGG (School of Psychology) Are there separate conflict-specific cognitive control mechanisms in the developing brain?

When multiple competing response options are available, adults' performance is impaired compared to when only a single option is possible. The anterior cingulate cortex (ACC) is thought to play a key role in detecting and overcoming conflict between response alternatives. The presence of competing stimuli in the environment also impairs adults' performance, although to a lesser extent. Moreover, there is some debate as to whether stimulus conflict is also dealt with by the ACC or by a separate neural mechanism. My research has shown that children show the opposite pattern to adults, experiencing greater interference from distracting stimuli than competing responses. This suggests that stimulus and response conflict may be dealt with by separate neural mechanisms that mature at different rates. This project will explore this idea further, recording an electroencephalogram (EEG) while children and adults perform a modified version of the Eriksen flanker task. Event-related potentials (ERPs) will be compared for conditions where there is no conflict, only stimulus conflict, or both stimulus and response conflict. This research will increase our understanding of cognitive control and how it develops.

Dr Lucy CRAGG (School of Psychology) The common neural basis of response conflict and inhibition

In ADHD research, response inhibition paradigms (e.g. go/no-go- and stop-signal tasks) and response conflict paradigms (e.g. flanker tasks) are typically used interchangeably, and a deficit in performance is treated as evidence for dysfunction in a common neural system. The extent to which resolving competition between a response and no response is the same as dealing with conflict between two different responses is unclear however. This project will use fMRI to explore the common neural basis of response conflict and response inhibition in healthy adults while they perform a hybrid flanker, go/no-go task. This research will help to uncover the relationship between different aspects of cognitive control, as well as develop a more detailed understanding of cognitive control deficits in ADHD.

Dr Ruth FILIK (School of Psychology). How do people process irony?

Despite the fact that it is a common communicative tool, little is known about how people actually process irony during on-line language comprehension. However, from the literature on the communicative function of irony, a number of theories have emerged. The current project would examine eye movements OR event-related brain potentials (ERPs) as participants read ironic texts in order to test the predictions of contemporary theories of irony processing.

Initial reading
Filik, R. & Moxey, L.M. (2010). The on-line processing of written irony. Cognition, 116, 421-436.

Dr Maddie GROOM & Professor Peter LIDDLE (Division of Psychiatry, School of Community Health Sciences)

Measuring visual attention using magneto-encephalography

Neuroimaging research has recently recognised the importance of studying whole brain functional networks to understand the basis of cognitive functions. For instance, the 'salience network' (SN) is a network of brain regions that are co-activated in response to novel or attention-grabbing stimuli 1, while regions in the Default Mode Network (DMN), a network associated with 'mind wandering' and introspection, exhibit correlated deactivation during task performance 2. Recent research has reported dysfunction in these brain networks in schizophrenia 3 suggesting that disruption to functional brain networks may be at the heart of this complex psychiatric condition.

Previous research has used functional MRI, a technique with poor temporal resolution. Using magneto-encephalography (MEG) the student will investigate the time-course of activation of functional brain networks and how these map onto measures of performance during a cognitive task, in healthy adults. The student will be taught techniques in MEG data collection and analysis.

The project will be supervised by Dr Maddie Groom and Professor Peter Liddle (Division of Psychiatry, School of Community Health Sciences) whose primary research interests are in neuroimaging psychiatric conditions. The student will therefore have the opportunity to observe neuroimaging research currently being conducted with patient groups in the Division of Psychiatry and will work amongst scientists in the field.

References: 1. Seeley WW, Menon V, Schatzberg AF, Keller J, Glover GH, Kenna H, Reiss AL, Greicius MD. Dissociable intrinsic connectivity networks for salience processing and executive control J Neurosci. 2007 27(9):2349-56.

2. Raichle ME, MacLeod AM, Snyder AZ, Powers WJ, Gusnard DA, Shulman GL. A default mode of brain function. Proc Natl Acad Sci U S A. 2001 98(2):676-82.
3. White TP, Joseph V, Francis ST, Liddle PF. Aberrant salience network (bilateral insula and anterior cingulate cortex) connectivity during information processing in schizophrenia Schizophrenia Research 2010 123: 105–115.

Dr Mark HASELGROVE (School of Psychology): Modulation of attention via associative pretraining. An fMRI study

The concept of attention has been an important yet controversial aspect of animal learning theory. One model of attention (Mackintosh Psychological Review 1975) holds that attention is allocated to the best predictor of an outcome in a given array of stimuli. We plan to exploit the spatial dissociation of the representation of house and face stimuli in the temporal lobe and the modulation of neural activity in those regions as a metric of attention (e.g. Vuilleumier et al. Neuron 2001). House and face stimuli will be presented as pairs, and differential pretraining of the stimuli should lead to a differential allocation of attention, in accordance with the predictions of Mackintosh (1975), which should be reflected as differential activity in different regions of the temporal lobe. It is hoped that the investigation of this novel dependent measure will provide fresh insight into a longstanding question of the role of attention in associative learning.

Prof Georgina JACKSON and Prof Stephen JACKSON in co-operation with Dr Martin SCHÜRMANN

MEG for studies of cognitive control in response and task selection. Humans can override or suppress reflexive or habitual actions in favour of forms of response that are more likely to achieve our behavioural goals. Disorders of this function are observed in mental illnesses such as Tourette's syndrome where individuals exhibit unwanted behaviour that they find difficult to control. The mechanisms of cognitive control and their neural correlates were addressed by G.J. and S.J. in numerous earlier studies [1-3] that used behavioural measures, event-related potentials (ERPs), and fMRI.

The project requires evaluation of data from MEG experiments with tasks that are similar in cognitive control demands but different in response modes – either oculomotor or manual. A particular aim is to use the good spatiotemporal resolution of MEG for closer analysis of the parietal brain activity during task switching which has been observed in ERP studies [3,4]. The project is well suited for a student who is interested in MEG data analysis, both in source space (using distributed source models) and in sensor space (using the Fieldtrip toolbox [5] within Matlab scripts part of which the student will develop under guidance).

1. Swainson R. et al. (2003). Journal of Cognitive Neuroscience 15, 785-799.
2. Mueller SC et al. (2006) Current Biology, 16, 570-573.
3. Astle DE et al. (2006) Brain Res. 1125: 94-103.
4. Rushworth MFS et al. (2002) Journal of Cognitive Neuroscience 14: 1139-1150
5. http://www.ru.nl/neuroimaging/fieldtrip/

Prof Stephen JACKSON (School of Psychology): 1. Neural basis for unwanted thoughts and actions

Understanding the nature of the brain mechanisms that allow us to regulate our behaviour is a fundamental problem for neuroscience and is of considerable clinical importance in understanding and treating the consequences of mental illness. This is because behavioural dysregulation and/or disorders of cognitive control are strongly associated with a number of common mental illnesses including: Attention Deficit Hyperactivity Disorder [ADHD]; Tourette syndrome [TS]; and Obsessive Compulsive Disorder [OCD]. In this project we will use magnetic resonance imaging to investigate the functional anatomy of unwanted actions.

Prof Stephen JACKSON: 2. Neural circuits involved in the suppression of tics in Tourette syndrome

Tourette syndrome (TS) is a developmental neuropsychiatric disorder characterised by the presence of chronic vocal and motor tics. Tics are involuntary, repetitive, stereotyped behaviors that occur with a limited duration. The neurological basis of TS is unclear at this time however it is agreed that the basal ganglia, including circuits that link the striatum to the frontal lobes, are dysfunctional. It has been suggested that individuals who learn to successfully control their tics do so by recruiting an enlarged or enhanced network of cortical areas that are involved in the cognitive control f behaviour. In this project we will use neuroimaging techniques (e.g., functional MRI, diffusion tensor imaging, transcranial magnetic stimulation) to investigate and quantify this hypothesis.

Prof Stephen JACKSON: 3. Brain plasticity and functional re-organisation in the ageing brain

Both normal ageing and age-related neurodegenerative disorders such as Parkinson's disease (PD) are associated with specific forms of cognitive deficit: most particularly impairment in executive function and the cognitive control of behaviour. These cognitive impairments have been linked to neurobiological changes affecting the operation of the cortico-striatal circuits of the human brain. Recent studies have shown that the neurobiological changes and age-related cognitive decline associated with normal ageing can be significantly slowed, or even reversed, by regular cardiovascular [CV] exercise, and studies using a rat model have demonstrated that a cardiovascular exercise intervention can attenuate dopamine depletion in the striatum of hemi-parkinsonian rats, indicating that exercise may be neuroprotective. The aim of this project would be to investigate this hypothesis using behavioural measures of performance and neuroimaging techniques (e.g., functional MRI, diffusion tensor imaging, transcranial magnetic stimulation).

Prof Stephen JACKSON: 4. Neural representation of movement and updating of the 'body-schema'

Damage to the posterior parietal cortex can lead to a disorder of visually guided reaching movements known as optic ataxia (AO). We have previously suggested that the brain area most often associated with optic ataxia – the medial aspect of the posterior parietal cortex -- is important for maintaining a dynamic, up-to-date, representation of the postural configuration of the body [i.e., the body 'schema']. We will investigate this hypothesis by studying reaching movements to visually defined and posturally defined targets in neurologically healthy individuals and patients with optic ataxia. This project will make use of kinematic analyses of reaching movements and fMRI. My lab is equipped with 2-joint robot arm for measuring movement and also an MRI-compatible 2-joint robot for measuring movements in the MR scanner.

Prof Stephen JACKSON: 5. Mechanisms of functional re-organisation of sensorimotor function after stroke

Stroke is the leading cause of disability in the UK and one half of those surviving a stroke will be significantly disabled and require help with activities of daily living, either at home or in an institution. This project will investigate neural plasticity and functional re-organisation of sensorimotor function following a stroke. Current projects include the use of robot-based therapy to rehabilitate upper-limb function after stroke, and, the use of somatosensory stimulation to promote recovery of swallowing post stroke. The project will utilise one or more of the following techniques: magnetic resonance imaging; transcranial magnetic stimulation; motor learning/movement analysis using a 2-joint robot arm.

Prof Stephen JACKSON: 6. Neural basis for the modulatory effects of motor intention on perception

Psychophysical studies have repeatedly demonstrated that visual stimuli presented close to the onset of a saccadic eye movement are mislocalised spatially and temporally. Similarly, psychophysical and electrophysiological studies have demonstrated that the intention to execute a limb movement leads to reduced tactile sensitivity on the limb that is about to be moved. This project will use magnetic resonance imaging and/or transcranial magnetic stimulation techniques to investigate how motor intention influences tactile perception.

Dr Jon PEIRCE (School of Psychology) Understanding conjunction detectors in mid-level vision

My lab focuses on how the outputs of V1 might be combined by later visual areas. We study this using a variety of techniques, including psychophysics, fMRI, computational modelling and patient work. The psychophysical methods are generally most productive and easiest to learn for a short-term project. The following describes one possible theory to test (using psychophysics), but others are easily possible (and, potentially, using other methods).

We have previously shown that conjunction detectors can be demonstrated in the visual system using aftereffects such as the curvature aftereffect (Hancock & Peirce, 2008). We know that, at some point in the visual pathway, recognition of objects becomes 'translation invariant'; you can still recognise your mother regardless of where the image of her face falls on your retina. Are curvature detectors, as measured by the curvature aftereffect, translation invariant, or does this invariance occur at a later stage in the visual stream?

Dr Denis SCHLUPPECK (School of Psychology)Using high-resolution anatomical and functional MRI at 7T to measure responses to visual and somatosensory stimuli in the thalamus

(Background) Functional imaging of the midbrain challenging: at 7T distortions due to magnetic field inhomogeneities can cause problems; also physiological noise due to respiration, pulsatility, ... can dominate. Several recent publications have demonstrated that using 3T fMRI it is possible to reliably measure visually evoked responses in the lateral geniculate nucleus LGN, the thalamic relay station for visual information). In collaboration with colleagues at the SPMMRC centre we have successfully measured responses in the LGN at 7T using gradient-echo EPI (1.5mm isotropic voxels). The aim of this project will be to extend these results by functionally and anatomically localizing the ventral posterior lateral and medial nuclei, which form part of the somatosensory pathway.

(Things you would do/learn in this project)

• analyze (and help acquire) high-resolution functional MRI data on the 7T Philips scanner

• use standard topographic mapping techniques to measure maps in different parts of cortex

• try to reveal differential responses in thalamic nuclei (dorsal lateral geniculate nucleus [visual] and ventral posterior lateral nucleus [somatosensory]) in functional data and anatomical images

• learn matlab-based tools for analyzing data from 'traveling wave' (topographic mapping) paradigms.

• write a detailed report that would be useful to anyone wanting to acquire data in this way in future

(Things you need) To prevent disappointment and frustration on your part, you should have an interest in quantitative methods and some experience with computers in general, possibly Matlab and Unix. If you don't have those skills, yet, you could spend some time learning and teaching yourself basics of computer programming / scripting. If you are interested, but have concerns, don't hesitate to come and see me.

References:
Sanchez-Panchuelo, Francis, Bowtell, Schluppeck (2010) J Neurophysiol
http://www.ncbi.nlm.nih.gov/pubmed/20164393

(thalamic anatomy w/ MRI)
Deoni, Josseau, Rutt, Peters (2005) HBM
http://www.ncbi.nlm.nih.gov/pubmed/15852386

Deoni, Rutt, Parrent, Peters (2007) Neuroimage
http://www.ncbi.nlm.nih.gov/pubmed/17070073

(Methodology for visual cortex mapping)
Wandell, Dumoulin & Brewer (2006) Neuron
http://www.ncbi.nlm.nih.gov/pubmed/17964252

Larsson & Heeger (2006) JNeurosci
http://www.ncbi.nlm.nih.gov/pubmed/17182764

Dr Martin SCHÜRMANN (School of Psychology)

Motor cortex activation in the perception of hand postures and hand movement – an MEG study
A hand posture or movement can give away a person's intentions to an observer. In such a situation the observed hands appear in third-person (allocentric) perspective to the observer – as opposed to the observer's own hands which are perceived in first-person (egocentric) perspective. According to the direct matching hypothesis (Gallese et al. 1996), observed hand actions can be expected to activate the observer's motor cortex. Matching, however, requires that postures or movements observed in third-person perspective be transformed to first-person perspective.

Hand movement in ego- and allocentric perspective is known to activate anterior parietal cortex according to a functional MRI study (Shmuelof and Zolary 2008). Like comparable fMRI work, this study did not report motor cortex activation. In contrast, magnetoencephalography (MEG) is an established method to demonstrate primary motor cortex activation during action viewing (Hari et al. 1998) which is therefore to chosen for the proposed project.

The proposed project aims to identify neural correlates for these processes, using videotaped hand movement and still photos of hand postures as stimuli. The hypothesis is that (a) observed hand movement in first-person perspective activates motor cortex in the same areas that would be activated

during the observer's own action and (b) stimuli in third-person perspective lead to additional activation in parietal cortex.

References

Gallese V, Fadiga L, Fogassi L, Rizzolatti G. Action recognition in the premotor cortex. Brain 1996; 119: 593-609

Hari R, Forss N, Avikainen S, Kirveskari E, Salenius S, Rizzolatti G. Activation of human primary motor cortex during action observation: a neuromagnetic study. Proc Natl Acad Sci U S A. 1998; 95:15061-15065.

Shmuelof L, Zohary E. Mirror-image representation of action in the anterior parietal cortex. Nat Neurosci. 2008; 11:1267-1269.

Dr Martin SCHÜRMANN (School of Psychology) and Dr Sue FRANCIS (Sir Peter Mansfield Magnetic Resonance Centre)

Brain basis of audiotactile interaction. Many perceptual events in everyday life are multisensory. For example, the sounds arising when the hand explore a surface contribute to the explorer's haptic percepts. As a possible brain basis of such phenomena, functional brain imaging has identified activations specific to audiotactile interaction in secondary somatosensory cortex, auditory belt area, and posterior parietal cortex, depending on the quality and relative salience of the stimuli. This project focuses on the role of auditory cortex in the perception of vibrotactile stimuli. Given that auditory perception depends on fine analysis of temporal structures, the question is whether auditory cortex is activated when vibrotactile stimuli with certain temporal properties are processed. The project comprises psychophysical pilot experiments and fMRI measurements.

McGlone F, Kelly EF, Trulsson M, Francis ST, Westling G, Bowtell R. Functional neuroimaging studies of human somatosensory cortex. Behav Brain Res. 2002, 135:147-158.
Schürmann M, Caetano G, Hlushchuk Y, Jousmäki V, Hari R. Touch activates human auditory cortex. Neuroimage 2006, 30: 1325-1331.

Dr Deborah SERRIEN (School of Psychology):

The neural dynamics of handedness. In right-handers skilfulness associates with left hemisphere dominance for cognitive-motor control; a prioritization that has been attributed to anatomical and functional asymmetries of motor and association areas. As such right-handers have been extensively studied in the literature in contrast to other handedness groups. From the limited work that is available it has become evident that left-handers do not simply behave as a mirror image of right-handers. This project will evaluate the neural dynamics of skilled behaviour by means of EEG recordings in right- and left-handers.

Dr Deborah SERRIEN (School of Psychology):

The functional integration of hemispheric activity in motor control. With respect to motor behaviour, the prevalent view is that specialized functions of the left hemisphere are essential for movement control. Conversely the involvement of the right hemisphere is less defined, although it is known to have a dominant role in various spatially-related functions. Together, these contrasts in functional capacities of both hemispheres suggest that they provide distinct contributions to motor behaviour. This EEG project will assess the hemispheric (interactive) functioning during motor performance and modulations that occur due to contextual demands.

Dr. Deborah SERRIEN (School of Psychology):

Adaptation to temporal changes in sensorimotor synchronization. Temporal information processing is essential for behaviour, often with respect to external events. In the laboratory, this type of task is usually studied by means of finger tapping to auditory stimuli. Overall, it is observed that the taps precede the external cues by about 20-80 ms, a phenomenon called negative asynchrony. This behavioural project will evaluate the flexibility of the negative asynchrony delay and how it varies due to context and expertise.

Dr Alastair D. SMITH (School of Psychology) Navigational abilities of individuals with hydrocephalus

Neuropsychological testing has revealed that individuals with hydrocephalus (with or without spina bifida) demonstrate particular impairments on spatial memory and executive function measures. This project will assess how these impairments impact upon important everyday navigational abilities. Effective navigation can be broadly separated into two facets: landmark-based navigation, utilising the visual world for cues, and path integration, which is the updating of spatial position based on self-movement information (i.e. vestibular cues). The present study aims to test both of these functions in people with hydrocephalus and spina bifida. Not only will this be the first attempt to test more real-world behaviours in this population (from a cognitive neuroscience perspective), but it will also help to identify areas of difficulty which may benefit from remedial intervention.

Further reading

Iddon J. L., Morgan D. J., Loveday C., Sahakian B. J. and Pickard J. D. (2004) Neuropsychological profile of young adults with spina bifida with or without hydrocephalus. J. Neurol. Neurosurg. Psychiatry, 75, 1112–1118.

Janzen, G. & van Turennout, M. (2004). Selective neural representation of objects relevant for navigation. Nat Neurosci, 7, 673 – 677.

Smith, A. D., & Cohen, G. (2008). Memory for places: routes, maps, and object locations. In M. Conway & G. Cohen (Eds.), Memory in the Real World (3rd Ed.). Psychology Press. pp. 173-206.

Prof Chris STARMER (Centre for Decision Research and Experimental Economics) and Dr Martin SCHÜRMANN (School of Psychology) Brain correlates of financial risk evaluation: testing the evaluability hypothesis

This project aims to study brain correlates of how individuals evaluate risks. Existing research has demonstrated a curious behavioural phenomenon whereby increasing the objective attractiveness of a bet can apparently reduce it's attractiveness to would-be bettors. One example due to Paul Slovic is as follows. One group of individuals is asked to evaluate (on, say a 20 point ratings scale) the attractiveness of a bet that gives a 1/6 change of winning £9 (otherwise nothing). Another group of subjects is asked to evaluate a gamble which gives a 1/6 change of winning £9 and a 5/6 chance of losing 10p. While the second bet seems unambiguously worse, ratings for it tend to be significantly higher. One explanation for this effect is the 'evaluability hypotheses' which assumes that individuals find it relatively hard to evaluate the attractiveness of (things like) money because there is no definite scale on which to judge 'how good is £9'. The project will use fMRI to study risk-evaluation-related activition in reward-related brain circuits and in brain regions implicated with magnitude or number processing.

Prof Chris STARMER (Centre for Decision Research and Experimental Economics) and Dr Martin SCHÜRMANN (School of Psychology) Brain correlates of coordinated decisions

Imagine the following situation. You have been paired with one other person. Each of you has to write down the name of a colour. The pair of you each win a prize if you write down the same colour. The problem is that you cannot communicate with each other. What would you do? Since there are many possible colours which you could say, without some means of coordinating responses one might think that the chances of coordination on the same colour are poor. But, empirical research demonstrates that people are in fact surprisingly good at coordinating in these types of problems (for example, if you respond with red or blue, there is a high probability of coordinating with the other person because most people in fact choose one of these colours). The research question for this project is 'how do people manage to solve coordination problems like this'. There are broadly two types of theory and an interesting difference between them is that invoke different types of mental processes. One class of theory assumes that some individuals simply pick the first thing that comes to mind. Coordination is then a consequence of correlation of the things that happen to come to mind for different people. Another class of theory presumes that individuals engage in sophisticated reasoning processes that lead to increased probability of coordinated outcomes. The project will use fMRI to study decision-related brain activation.