The time schedule for
“International symposium on Prediction and Decision Making”

Day1: October 31, 2015

8:00-9:00 Registration
9:00-9:20 Opening Remarks Kenji Doya

Session1: Neural Circuit for Decision Making Chair : Takatoshi Hikida

9:20- 9:50 Robert Malenka
9:50-10:20 Anatol Kreitzer
10:20-10:40 Coffee Break
10:40-11:10 Bernard Balleine
11:10-11:40 Catharine A. Winstanley
11:40-12:00 Katsuyuki Kaneda
12:00-12:20 Takayuki Teramoto

12:20-13:20 Lunch

13:20-15:00 Poster session

Session2: Social and Affective Decision Making Chair : Mitsuhiro Okada

15:00-15:30 Toshio Yamagishi
15:30-16:00 John Philip O’Doherty
16:00-16:20 Masahiko Haruno
16:20-16:40 Coffee Break
16:40-17:00 Satoshi Umeda
17:00-17:20 Takafumi Minamimoto
17:20-17:40 Hitoshi Okamoto

Special Lecture Chair : Minoru Kimura

18:00-19:00 Wolfram Schultz

19:15-21:30 Reception

Day2: November 1, 2015

8:00-9:00 Registration

Session3: Model-based Decision Making Chair : Masashi Sugiyama

9:00- 9:30 Nathaniel Daw
9:30- 9:50 Masamichi Sakagami
9:50-10:20 David Redish
10:20-10:50 David Foster:
10:50-11:10 Coffee Break
11:10-11:40 Sophie Deneve
11:40-12:00 Akihiro Funamizu
12:00-12:20 Yu Ohmura
12:20-12:40 Akio Namiki

12:40-13:40 Lunch

13:40-15:20 Poster session

Session4: Computational Psychiatry Chair : Tomohiro Shibata

15:20-15:50 P. Read Montague
15:50-16:20 Mitsuo Kawato
16:20-16:50 Mathias Pessiglione
16:50-17:10 Coffee Break
17:10-17:40 Michael J. Frank
17:40-18:00 Hidehiko Takahashi

18:00-18:30 General discussions

Robert Malenka

Stanford University

Day 1: October 31st 9:20 - 9:50

Exploring circuits underlying reward and aversion

A fundamental behavioral principle is Thorndike's law of effect: behaviors that lead to rewards will be repeated while behaviors that lead to aversion will not. Thus, delineating the neural circuits that mediate reward and aversion is an important topic with important implications for understanding adaptive and pathological decision making. This talk will review evidence that midbrain ventral tegmental area (VTA) dopamine (DA) neurons are not homogeneous but instead are embedded in distinct circuits that contribute differentially to reward and aversion. While activation of inputs to the VTA from the laterodorsal tegmentum (LDT) is reinforcing, activation of inputs from the lateral habenula (LH) is aversive. Electrophysiological recordings revealed that LDT neurons preferentially synapse on DA neurons projecting to NAc lateral shell while LH neurons synapse primarily on DA neurons projecting to mPFC as well as on GABAergic cells in the RMTg. These results suggest that specific VTA circuits involving distinct subpopulations of DA neurons contribute to the generation of reward and aversion. To further elucidate the detailed input-output relationships within these complex VTA circuits, a new rabies virus based method of circuit tracing has been applied and results from these experiments will also be presented.

Anatol Kreitzer

Gladstone Institutes / University of California San Francisco

Day 1: October 31st 9:50 - 10:20

Function of Basal Ganglia Circuits in Movement and Action Selection

Neural circuits of the basal ganglia are critical for adaptive motor control and have been implicated in both neurological and psychiatric disorders. Two parallel basal ganglia pathways have been described: the direct and indirect pathways. Optogenetic activation of the direct pathway increases movement and is sufficient for reinforcement, whereas activation of the indirect pathway suppresses movement and may be involved in punishment. However, both pathways are co-active during normal movements, raising the question of how each pathway functions to coordinate adaptive motor behavior. We have used a combination of in vivo electrophysiology , fiber photometry, and imaging to record activity from distinct subpopulations of striatal neurons in mice performing a simple foraging task, in order to understand their specific roles in action selection.

Bernard Balleine

Brain & Mind Centre, University of Sydney

Day 1: October 31st 10:40 - 11:10

Inhibition and choice

In motivational terms, stimuli that predict the loss or absence of reward are often classed with those associated with aversive events and, indeed, in Pavlovian conditioning, the former have occasionally been reported to block learning about the latter. Nevertheless, it is not known how inhibitory predictors influence choice between goal-directed actions. In this talk I will describe several recent studies in which we investigated this question at both a behavioral and neural level in rodents. In these experiments we compared the influence of excitatory and inhibitory predictors of specific outcomes on the performance of actions that earned those outcomes and found consistent evidence that, in similar manner to excitatory predictors, stimuli predicting the absence of a particular outcome biased choice towards actions associated with the absence of that same outcome. Whereas the prediction of a common outcome allows stimulus-outcome associations to bias choice towards particular actions, it is the common prediction of the absence of a specific outcome that provides the basis for inhibitory predictions to bias choice. These experiments suggest, therefore, that excitatory and inhibitory predictors exert a broadly symmetrical influence on choice between goal-directed actions and that they do so through integration with excitatory and inhibitory action-outcome associations, respectively.

Catharine A. Winstanley

Djavad Mowafaghian Centre for Brain Health
University of British Columbia

Day 1: October 31st 11:10 - 11:40

The risks of risky choice: what can rodent models of maladaptive decision-making under uncertainty tell us about addiction disorders?

Maladaptive decision-making may play an integral role in the development and maintenance of an addicted state. However, it is unclear from clinical studies whether this cognitive impairment is a cause or consequence of the addiction. This talk will provide an overview of some of our recent work using different paradigms to model risky decision-making in rats to probe cognitive vulnerabilities to addiction-like states. We have shown using the rat gambling task (rGT) that rats are capable of “playing the odds” and discriminating between four distinct options, each associated with different magnitudes and frequencies of gains and losses, in order to maximize sugar pellet profits. However, if the rewards are accompanied by salient audiovisual cues that increase in size and complexity with the size of the reward, rats are less able to discern the appropriate strategy, and instead opt for high-risk high-reward options that ultimately results in lower net gains. The ability of reward-paired cues to elicit risky choice matches the experience of many human gambling games in which winning results in an appetitive sound and light display. Furthermore, animals that exhibit a preference for risky options at baseline are uniquely and adversely affected by cocaine self-administration. Although these risk-preferring rats did not self-administer more cocaine than their optimally-choosing counterparts, they responded more on the drug-paired lever, indicative of enhanced drug-seeking, and exhibited enhanced

cue-induced incubation of craving, suggestive of elevated relapse risk. The decision-making of the risk-preferring rats also became progressively worse during the same diurnal period as cocaine self-administration, and this deficit persisted during withdrawal. In striking contrast, the choice pattern of optimal decision-makers remained advantageous and unaffected by cocaine intake. Such findings indicate that the elevated risky decision-making observed in substance-dependent populations is not merely circumstantial, but makes an important contribution to addiction vulnerability and severity.

Katsuyuki Kaneda

Kanazawa University

Day 1: October 31st 11:40 - 12:00

Neural mechanisms of acute stress-induced enhancement of cocaine craving behavior

Stress affects motivated behaviors, including drug craving. In this study, we examined the effects of acute stress on cocaine-induced conditioned place preference (CPP), a measure to evaluate animal's cocaine craving behavior.

Rats were conditioned with a low dose of cocaine, and then, exposed to acute restraint stress for 30 min immediately before posttest. The CPP scores of stressed rats were significantly larger than those of non-stressed rats, indicating that stress enhances cocaine craving. Because stress increases locus coeruleus (LC) neuronal activity and the laterodorsal tegmental nucleus (LDT) receives dense noradrenaline (NA) input from the LC, we investigated the possible contribution of NA transmission in the LDT to the stress-induced enhancement of cocaine CPP. Intra-LDT injection of β or α2, but not α1, adrenoceptor inhibitor before stress exposure greatly reduced the stress-induced enhancement of cocaine CPP. Intra-ventral tegmental area (VTA) injection of either scopolamine, mecamylamine, or the mixture of APV and CNQX also reduced the stress-induced enhancement of cocaine CPP, suggesting the critical role of both cholinergic and glutamatergic transmissions from the LDT to the VTA. Additionally, microinjection of D1 but not D2 receptor antagonist into the medial prefrontal cortex (mPFC) attenuated the stress-induced enhancement of cocaine CPP.

Taken together, these results suggest that stress-induced NA release in the LDT,

which is followed by increases in cholinergic and glutamatergic transmissions in the VTA, and a resultant facilitation of dopaminergic signaling in the mPFC may contribute to the stress-induced enhancement of cocaine craving behavior.

Takayuki Teramoto

Kyushu University

Day 1: October 31st 12:00 - 12:20

Whole-brain Ca^{2+} imaging of *C. elegans* to explore the neuronal mechanisms for behavioral choice

The central nervous system (CNS) processes a variety of sensory information from environment to execute a proper action. This kind of sensory processing is crucial to ensure survival even for simple organisms.

A simple model organism, *C. elegans,* shows the behavioral choice through sensory integration under conflicting situation between repellant metal ion and an attractive odorant, which is regulated by a local circuit in the CNS. Because *C. elegans* has the transparent body and the simple CNS that consists of about 180 neurons, whose connectivity has been described completely, it is an excellent model system to apply whole-brain imaging for approaching the neuronal mechanisms for the behavioral choice.

To visualize the neuronal activities of the whole CNS, we designed a 4D imaging system and developed a line of programs that track cell-position and determine cell-border of the each neuron in a live animal. Using this imaging system, we succeeded in measurement of most neuronal activities in the CNS. Time series analyses revealed that some neurons responded with positive and negative correlation to stimulation by such as an attractive odor and a repulsive metal ion. This result may suggest that these neurons are components of the neuronal circuit that are involved in the sensory signaling pathway or/and it's processing.

The 4D imaging system, therefore, enable us to visualize and measure the

whole-brain activity of an intact *C. elegans* at cellular resolution. This imaging technique may open a new window to explore neuronal mechanisms not only for the behavioral choice through sensory integration, but also other kind of information processing by the brain.

Toshio Yamagishi

Hitotsubashi University

Day 1: October 31st 15:00 - 15:30

Heuristic and Deliberative Decision Making in Five Economic Games

Using data obtained from 523 non-student Japanese participants (age 20-60) who played five economic games, I addressed the question raised by the social heuristic hypothesis (Rand et al., 2012) if deliberate decision makers are less cooperative across the five games than heuristic (or fast) decision makers. The answer to this question depended on the participant's social value orientation (SVO)—which is a measure of the participant's default cooperative tendency. Fast decision makers were more cooperative than slow decision makers among pro-socials, and fast decision makers were less cooperative among pro-selfs. Among slow decision makers, the well-established effect of SVO on cooperative choices was greatly reduced. Responses to an emotional reappraisal scale (Gross & John, 2002) was also found to be negatively correlated with the overall cooperation levels and pro-social preferences (as they were measured by SVO) of the participants. The positive relationship between overall cooperation levels and decision times was pronounced among pro-self participants regardless of the levels of emotional reappraisal. The heuristic cooperation hypothesis was supported only among pro-social participants, especially those who are weak in emotional reappraisal—possibly those who are directly affected by negative emotions derived from not cooperating.

John Philip O'Doherty

California Institute of Technology

Day 1: October 31st 15:30 - 16:00

Neural mechanisms underlying learning and inference in a social context

Considerable progress has been made in understanding the neural computations underlying the capacity of the human brain to learn from experience and in making decisions to maximize future rewards. Much less is known about how the brain is able to learn and make decisions in a social context. In this talk I will outline a computational model-based approach in which we combine computational modeling with fMRI experiments in order gain insight into how it is that the brain is capable of learning from and about other people, as well as to ascertain how it is the brain can make use of the knowledge acquired about or from others in order to make good decisions in a social context. Our findings point to the involvement of multiple mechanisms in social learning and decision-making. Some of these are domain general i.e. involved in both social and non-social contexts, while other brain mechanisms may be more domain specific, i.e. with a relatively more specialized involvement only in social contexts.

Masahiko Haruno

NICT Cinet

Day 1: October 31st 16:00 - 16:20

Brain Response Patterns to Inequity Can Predict Long-term Changes in Depression Tendency

Widening social inequity is a key concern for modern society, and is also implicated in several psychiatric diseases, including depression. Although previous cohort-based studies have indicated a link between inequity and depression, little is known about the neural mechanism, mainly due to substantial individual differences. Here, we demonstrate that activity patterns in the amygdala/hippocampus induced by inequity can predict long-term (one-year) changes in depression tendency. This finding provides the first experimental evidence that links brain response to inequity and future depressive tendency.

Satoshi Umeda

Keio University

Day 1: October 31st 16:40 - 17:00

Probabilistic decision making and autonomic nervous activities

Previous functional neuroimaging studies provide evidence of the relationship between autonomic bodily responses and decision making. However it remains unclear how primary autonomic disorders influence probabilistic decision making. The present neuroimaging study investigates how heightened bodily reactivity affects decision making under uncertain conditions. We recruited patients with postural tachycardia syndrome (PoTS) and age-matched controls. PoTS, a form of hyperautonomic disorders, is characterized by orthostatic intolerance, and is frequently accompanied by a range of symptoms including palpitations, lightheadedness, clouding of thought, blurred vision, fatigue, anxiety, and depression. Although the estimated prevalence of PoTS is approximately 5-10 times as common as the better-known condition orthostatic hypotension, the neural substrates of the syndrome are poorly characterized. In the present study, we used magnetic resonance imaging (MRI) with VBM-DARTEL procedure to examine variation in regional brain structure associated with PoTS. Group comparison of gray matter volume revealed diminished gray matter volume within the salience network including the left anterior insula and right cingulate gyrus in the PoTS group. Subsequent ROI analyses revealed significant negative correlations between left insula volume and trait anxiety and depression scores. As a functional MRI study, participants were scanned with heart rate recording while performing a probabilistic reasoning task similar to the bead counting task (Moritz & Woodward, 2005). The proportions of beads in two containers were explicitly stated and participants were told that a computer would randomly draw beads from one or other container throughout the

task. On each draw they were asked to reason about which container had likely been used and to press a button only when they made a final judgment. The scores of the personality questionnaires indicated that the PoTS patients showed significantly higher state and trait anxiety, higher depressive status, and nearly half of the patients had past experience of panic attacks. At the behavioural level, the PoTS patients showed more trials for making final decisions compared to controls, whereas correct response ratios in both groups were not different. At the physiological level, only control showed decrease in heart rate from onset of the trails to the decision. For the fMRI data analysis, we set the order of presented beads in each trial as a parametric modulator to find areas correlated with increasing certainty of the distribution. The results showed significant activations in right anterior insula, right thalamus, anterior cingulate cortex, and the periaqueductal gray in the patients compared to controls. Overall findings suggest that heightened bodily states trigger more deliberate decision making. This would be based on the excessive autonomic processing with higher interoceptive awareness. These patterns of bodily reactivity and decision making bias may elicit more anxious and depressive mood status in the patients. Our study highlights the possible neural mechanisms for understanding the relationship between decision making and emotional processing in primary autonomic hyperreactivity disorder.

Takafumi Minamimoto

National Institute of Radiological Sciences

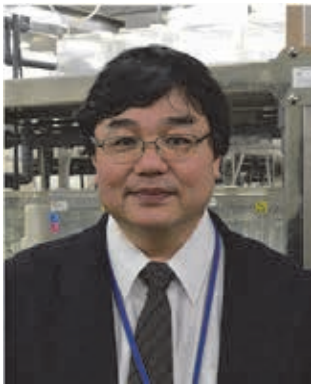
Day 1: October 31st 17:00 - 17:20

The role of dopamine and serotonin in value-based decision-making in normal and disease state

Dopamine (DA) and serotonin (5-HT) are two neuromodulatory systems that are implicated in motivational functions in both normal and disease states. To identify specific roles of DA and 5-HT systems in *loss of motivation*, one of the core symptoms of depression, we studied a monkey model of hypothyroidism, adult patients of which often show this symptom. Hypothyroidism monkeys showed low dopamine and serotonin level in their CSF. In addition, their goal-directed task performance worsened without increasing reaction time, indicating decreased motivational level. The decreased motivation can be explained by two factors, reward-value-dependent andreward-value-independent ones. Each of these two motivational factors independently became normal by treatment with L-dopa or SSRI, suggesting that loss of DA and 5-HT causes loss of motivation in value-dependent and -independent ways, respectively. This behavioral dichotomy was consistently found in further pharmacological experiments; systemic application with D2R antagonists resulted in value-dependent loss of motivation, whereas value-independent loss of motivation occurred in 5HT depletion or with systemic 5-HT1A antagonist. These results suggest distinct roles for the two neuromodulator systems in value-based decision-making and motivational control. DA has a consistent role in the value-related process in normal and disease, whereas low 5-HT induces a general decrease of motivation orthogonally to the value-related process.

Hitoshi Okamoto

RIKEN Brain Science Institute



Day 1: October 31st 17:20 - 17:40

Control of Social Aggression by the Habenula

Many animals fight to determine the dominant-subordinate relationship for securing better living conditions such as in nutrition, territory, and reproduction. We discovered that different subnuclei of the habenula regulate the social aggression in distinctive manners. The habenula (Hb) is an evolutionarily conserved diencephalic structure. In zebrafish, the lateral and medial subnuclei of the dorsal habenula (dHbL and dHbM) are asymmetrically connected with the dorsal/intermediate and ventral/intermediate parts of the interpeduncular nucleus (d/iIPN and v/iIPN), respectively. The vHb projects to the serotonergic neurons in the ventro-anterior corner of the medial raphe (MR). We performed Ca-imaging in the acute slice of the adult zebrafish brain immediately after the fight by stimulating the Hb. In the winner fish, the activity which reached the IPN from the Hb further propagated to the dorsal raphe and the dorsal tegmental area, while it propagated to the ventral structures. We discovered that, in the fight between two normal fish, the fish which bite more frequently in the first one minute increase the frequency of biting in the following period of fight and eventually win, while the fish which bite less frequently at the beginning fail to do

Wolfram Schultz

University of Cambridge

Day 1: October 31st 18:00 - 19:00

The dopamine reward utility signal and its two components

Dopamine neurons respond to rewards with two components, similar to higher order sensory and cognitive neurons. They show an initial, rapid, unselective response that reports all salient environmental events irrespective of their reward association. It is highly sensitive to factors related to reward and thus detects a maximal number of potential rewards. Although the first component detects punishers by their physical impact, none of the components codes the aversive nature of punishers. The second response component processes reward value accurately and starts early enough to prevent confusion with unrewarded stimuli and objects. Quantitative behavioural tests allow us to assess the common currency relationship of dopamine responses to subjective value derived from risk, different rewards and temporal discounting. Neuronal satisfaction of first and second order stochastic dominance suggests meaningful processing of value under risk and incorporation of risk into subjective value. Assessment of economic utility goes one step further and determines subjective value as mathematical function of objective value (of liquid reward). The dopamine reward signal follows closely the nonlinear utility function and thus codes a numeric, quantitative utility prediction error. These data unite concepts from animal learning theory and economic decision theory at the level of single reward neurons. Thus, the dopamine reward signal is fast, highly sensitive and appropriate for driving and updating economic decisions.

Nathaniel Daw

New York University

Day 2: November 1st 9:00 - 9:30

Model-based decision making and compulsion

One of the most promising aspects of multiple decision system theories is that they might help to explain the mysterious and deleterious phenomenon of compulsion. In particular, it has been suggested that the compulsive aspects of drug abuse and a number of other disorders might reflect a common deficit in the balance between model-based and model-free decision processes. Indeed, deficits in model-based decision making have been observed in a number of compulsive disorders. However, the specificity of these results has not been estabilshed, as similar deficits have also been reported in other disorders, such as social anxiety, which are not characterized by compulsive, repetitive acts.

A similar lack of specificity is unfortunately ubiquitous in psychiatry research. We hypothesized that this might, in part, reflect the poor discriminative validity of the psychiatric diagnostic categories, and therefore that a trans-diagnostic, dimensional approach leveraging the efficiencies of large-scale online data collection among healthy individuals could be used to more precisely characterize the neurobiological basis of compulsivity. Using large-scale online testing of variation in psychiatric symptoms and model-based decision making performance in two large samples (about 2000 subjects in all), we found evidence that individual differences in decision making were linked to compulsive symptoms that generalized across a number of disorders. Moreover, we found that the relationship between model-based deficits and compulsivity was highly

specific, compared to non-compulsive psychopathology including symptoms of mood disorders and aspects of schizotypy. These data showcase a powerful new methodology and provide support for the potential of a dimensional, computationally grounded approach to psychiatry research.

Masamichi Sakagami

Brain Science Institute, Tamagawa University

Day 2: November 1st 9:30 - 9:50

Functional difference of reward inference in the lateral prefrontal cortex and the striatum and its integration

It has been suggested that the brain contains multiple yet distinct systems involved in reward prediction. Several studies have tried to allocate model-free and model-based systems to the striatum and the lateral prefrontal cortex (LPFC), respectively. Although there is much support for this hypothesis, recent research has revealed discrepancies. To understand the nature of the reward prediction systems in the LPFC and the striatum, a series of single-unit recording experiments were conducted. LPFC neurons were found to infer the reward associated with the stimuli even when the monkeys had not yet learned the stimulus-reward associations directly. Striatal neurons seemed to predict the reward for each stimulus only after directly experiencing the stimulus-reward contingency. However, the one exception was “Exclusive Or” situations in which striatal neurons could predict the reward without direct experience. Previous single-unit studies in monkeys have reported that neurons in the LPFC encode category information, and represent reward information specific to a group of stimuli. We suggest that the functional difference in reward prediction between the LPFC and the striatum is that while LPFC neurons can utilize abstract code, striatal neurons can code individual associations between stimuli and reward but cannot utilize abstract code. Also, we will consider how those pieces of information are integrated mentioning to our recent study with DREADDs.

David Redish

University of Minnesota

Day 2: November 1st 9:50 - 10:20

Interactions between decision-making systems - implications for behavioral economics

The idea that behavior is driven by multiple decision-making systems is now very well established. Current theories suggest that there are four action-selection systems competing for behavioral control - reflexes, Pavlovian action-selection, Deliberative systems, and Procedural systems. Over the last several years, we have been able to identify how information is differentially processed in each of these systems and to observe the information processing in many of the underlying neural systems in the behaving rat. In my presentation for this symposium I will talk about our recent data looking at manipulations of and transitions between these systems. In particular, I will discuss the implications for behavioral economics and addiction treatments.

David Foster

The Johns Hopkins University School Of Medicine

Day 2: November 1st 10:20 - 10:50

Hippocampal place-cell sequences for learning and decision-making

It is now well known that hippocampal place cells exhibit spatially-localized “place field” responses during spatial exploration. Place cells can also be activated outside of their place fields in the same environment, during sharp-wave/ripple events in the local EEG, in which case they take part in sequences representing multiple locations. Place-cell sequences lasting up to a few hundred milliseconds depict spatial trajectories through experienced environments, on a timescale that is 10-20 times faster than behavior. Two formats for place-cell sequences have been reported: forwards-ordered and reverse-ordered. Here I will discuss evidence that forwards and reverse sequences have separable roles in learning from rewards and decision-making. These results add to the emerging picture of highly dynamic processing by hippocampal place cells, with direct relevance to cognition.

Sophie Deneve

CNRS

Day 2: November 1st 11:10 - 11:40

Spike-based Population Coding and Bayesian Inference

Hallucinations and delusions are characteristic symptoms of schizophrenia. Recent experimental and computational studies suggest that subtle impairments of excitatory-to-inhibitory (E/I) balance or regulation are involved in many neurological and psychiatric conditions, including schizophrenia.

Considering how the brain constructs hierarchical, causal models of the external world, we show how an impairment of local inhibition and/or an excess of long range excitation can result in not only hallucinations but also the formation and subsequent consolidation of delusional beliefs. The consequence of such imbalance in a neural hierarchy can indeed be equated to "circular Bayesian inference": Bottom-up sensory evidences are combined not only with prior knowledge, but also with their own reverberated top-down predictions. Vice versa, prior predictions can activate sensory representations and be misinterpreted as “external” sensory evidence. Circular inference accounts for the emergence of erroneous percepts, the patient’s overconfidence when facing probabilistic choices, the learning of “unshakable” causal relationships between unrelated events and a paradoxical immunity to perceptual illusions.

In order to test this model more quantitatively, we asked schizophrenia patients to report their level of confidence in a two alternative choices, while manipulating the strength of sensory evidence and prior information. We found that patients are generally over-confident compared with healthy controls, but exhibit great variability in their

behavior. Their responses are well fitted by a parametric model quantifying the “severity” of circular inference, which is correlated with the severity of their positive symptoms and non-clinical beliefs. More generally, our result suggest that hallucinations and delusions are due to over-interpretations of the sensory evidence rather than a dominance of unfounded prior beliefs.

Akihiro Funamizu

Okinawa Institute of Science and Technology Graduate University

Day 2: November 1st 11:40 - 12:00

Neural substrate of Bayesian dynamic filter in posterior parietal cortex

Our brain often receives limited sensory information to understand the state of the outside world. Therefore the ability to estimate the current state through mental simulation is essential. In a stochastic dynamic environment, this state estimation is optimally realized by a Bayesian dynamic filter. Here we show that the mouse posterior parietal cortex (PPC) implements two fundamental factors of a Bayesian dynamic filter, which are prediction of a new state by an internal state transition model and its updating based on sensory evidence. We optically imaged the calcium transients of PPC neurons and its adjacent region (posteromedial cortex: PM) during an auditory virtual navigation task in which guiding sounds were intermittently presented. PPC neurons but not PM neurons in layers 2, 3 and 5 represented the goal distance, which changed with the animal's locomotion, even when guiding sounds were omitted (prediction). Uncertainty of the estimated goal distance decreased during sound inputs (updating). The result suggests that the cortical microcircuits implement Bayesian dynamic filter for state estimation and that PPC takes a role in the estimation of a target location using an action-dependent state transition model.

Yu Ohmura

Hokkaido University Graduate School of Medicine

Day 2: November 1st 12:00 - 12:20

Optogenetic control of central serotonergic neurons affects impulse control and model-based decision making

It has been speculated that serotonin release in the forebrain is involved in impulse control and model-based decision making. However, there is so far no direct evidence proving this hypothesis because there had been no method that reversibly, selectively, and temporally-specifically controls serotonergic activity. Therefore, we aimed to obtaining direct evidence about the effects of acute serotonin release on impulsivity and model-based decision making using recently developed optogenetic tools.

We obtained transgenic mice expressing channelrhodopsin-2 (ChR2) mutant (C128S) or Archaerhodopsin T (ArchT) only in central serotonergic neurons. We applied blue light to the dorsal raphe nucleus (DRN) or the median raphe nucleus (MRN) to open ChR2, and recorded impulsive action. Yellow light was applied to the DRN to open ArchT, and recorded model-based decision making. A 3-choice serial reaction time task (3-CSRTT) was used to assess impulsive action. A lithium devaluation task was used to assess model-based decision making. In this paradigm, a mouse is first trained to poke its nose to illuminated holes to get a food pellet, and then the food is devalued by pairing it with lithium-induced illness.

Optogenetic activation of serotonergic neurons in the DRN or MRN suppressed impulsive action without affecting other cognitive/motor parameters in the 3-CSRTT. Although inconclusive, preliminary results indicated that optogenetic silencing of serotonergic neurons in the DRN impaired model-based decision making. The number of nose poking responses after the devaluation procedure was reduced in wild type

mice while it was not reduced in ArchT-expressing mice. The consumed amount of devalued food was significantly decreased in either wild type or mutant mice. Thus it is likely that central serotonergic activity has a pivotal role in impulse control and model-based decision making.

Akio Namiki

Distinguished McKnight University / University of Minnesota

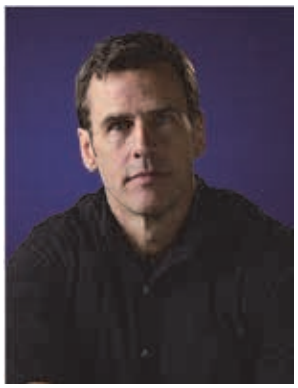
Day 2: November 1st 12:20 - 12:40

A decision-making algorithm for an air-hockey robot depends on its opponent player's motions

In this study, we propose a novel air-hockey robot that can select the optimal actions according to the behaviors of the opponent human player. In the robot, its attack behaviors are optimized during an air-hockey game by recognizing the motions of the puck and the human hand. First, how to calculate the attack position is explained. Secondly, the algorithm for decision making by the value of an attack based on the puck and the position of the human hand is explained. Then, we show the data of experiments and explain the reason of robot behaviors by the calculated value.

P. Read Montague

The Wellcome Trust Centre for Neuroimaging,
University College London
Virginia Tech Carilion Research Institute and
Computational Psychiatry Unit, Virginia Tech



Day 2: November 1st 15:20 - 15:50

A superposition of errors: sub-second dopamine fluctuations in human striatum encode superposed error signals about actual and counterfactual reward.

In the mammalian brain, dopamine is a critical neuromodulator whose actions underlie prediction learning, decision-making, and behavioral control.
Degeneration of dopamine neurons causes Parkinson's disease while dysregulation of dopamine signaling is believed to contribute to psychiatric conditions such as schizophrenia, addiction, and depression. Experiments in animal models
support the hypothesis that dopamine release in human striatum encodes reward prediction errors during ongoing decision-making. Blood- oxygen-level-dependent (BOLD) imaging experiments in humans support the idea that these errors are tracked by neural responses in the striatum; however, BOLD measurements cannot be used to infer the action of any one specific neurotransmitter. We monitored dopamine levels with sub-second temporal resolution in humans (N=17) with Parkinson's disease while they executed a sequential decision-making task. Participants placed bets and experienced monetary gains or losses. Dopamine fluctuations in the striatum fail to encode reward prediction errors as anticipated by a large body of work in model organisms. Instead, sub-second dopamine fluctuations encode an integration of reward prediction errors with counterfactual prediction errors; the latter defined by how much better or worse the experienced outcome could have been. These results have implications for the kinds of information thought to be carried by dopamine delivery.

Mitsuo Kawato

ATR Computational Neuroscience Laboratories

Day 2: November 1st 15:50 - 16:20

Psychiatric disorders as dynamic diseases

Resting-state functional brain connectivity (rs-fcMRI) is defined as temporal correlations between BOLD signals, and can quantify different brain dynamics. Each psychiatric disorder has been characterized by specific abnormal connectivity between specific brain regions. Many psychiatric treatments were found to normalize the aberrant connectivity, and the curative effect was correlated with the induced connectivity change. However, no treatment can selectively change the specified connectivity. Fukuda Megumi et al. (2015) developed a “connectivity” real-time fMRI neurofeedback (rt-fMRI NF) to change the functional connectivity between two specified brain areas. Previous classification of psychiatric disorders based on rs-fcMRI did not generalize well beyond a single imaging site. We selected as small as 0.2% of all functional connections (FCs) to classify high-functioning adult autism spectrum disorder (hASD) patients. 82% correct rate was obtained for multiple Japanese sites, and the biomarker generalized to US data with 75% (Yahata et al. 2013). Shibata et al. (2011) developed the “decoded neurofeedback”(DecNef) method by which specific brain activity patterns can be induced noninvasively utilizing rt-fMRI NF. It is possible to combine the above mentioned hASD biomarker, connectivity rt-fMRI NF and DecNef to construct a new therapy for psychiatric disorders (Hashimoto et al. 2013).

Mathias Pessiglione

ICM Brain & Spine Institute

Day 2: November 1st 16:20 - 16:50

Why don’t you make an effort? Computational dissection of motivation disorders

Apathy can be defined as a reduction of goal-directed behavior. It is frequently observed in psychiatric and neurological diseases, and presently assessed using clinical questionnaires. To understand the neural dysfunction underlying apathy, it is necessary to decompose this syndrome into elementary computational processes. A key motivational process is the arbitrage between costs and benefits: apathy can result either from hyposensitivity to potential rewards or from hypersensitivity to potential efforts. In this talk, I will present a behavioral paradigm that implements the conflict between effort and reward in humans, the crucial feature being that payoff is proportional to the energy expended. As suggested by model-based analyses of neuroimaging and patient studies, such a paradigm might provide some insights into the brain mechanisms underlying normal and deficient motivation, as well as treatment effects. For instance, dopamine agonists appeared to enhance reward attractiveness, whereas serotonin reuptake inhibitors seemed to alleviate effort cost.

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Michael J. Frank

Brown University

Day 2: November 1st 17:10 - 17:40

What do you do when you don't know what to do : Probing for informativeness on latent states during value-based decision making

Learning and decision making are complicated by the fact that observed events (e.g., your flight departing on time) are often determined in part by unobserved processes (e.g., the weather conditions en route). The advantage of considering latent processes is evident when events are predictable if considered in concert with their latent influences, but appear random otherwise. In reward-based learning, recent studies have suggested that humans direct exploratory behaviors toward those actions that reduce uncertainty about their underlying values. However, little work has examined whether participants actively select actions that would reduce uncertainty about the latent states, even when these actions themselves are known to carry little value. An optimal solution to the problem can be calculated for the setting that we study, but is computationally demanding. We propose a heuristic model that defines subjective utility in terms of both immediate expected value and the mutual information shared between action outcomes and latent states, where informativeness is increasingly weighted when latent states are particularly uncertain. Behavioral and electrophysiological (EEG) data show dissociable contributions of informativeness and reward value to choice, and individual differences in their relative weightings might contribute to aberrant choices in clinical populations.

Hidehiko Takahashi

Department of Psychiatry, Kyoto University
Graduate School of Medicine

Day 2: November 1st 17:40 - 18:00

Flexible modulation of risk attitude during decision-making under quota and its impairments in gambling disorders

Risk attitude is often regarded as an intrinsic parameter in the individual personality (‘individual preference’ view). On the other hand, ethological studies reported state-dependent modulation of risk attitude irrespective of the individual preference (‘state-dependent modulation’ view). To synthesize the two contrasting views, we developed a novel gambling task that dynamically manipulated the quota severity in a course of choice trials. As expected, participants flexibly modulated risk attitude according to the quota severity. They showed their individual risk preference when they had no quota constraint, while they uniformly adopted optimal risk attitude when they needed to achieve a quota. In the fMRI analyses, activation patterns in the dorsal anterior cingulate cortex (dACC), right anterior insula (AI) and dorso-lateral prefrontal cortex (dlPFC) reflected the quota severity. Furthermore, functional-connectivity analyses highlighted that the functional coupling between dlPFC and the dorso-medial prefrontal cortex (dmPFC) played a central role for the utilization of individual risk preference and state-dependent risk attitude.

Based on these findings, we applied this method to gambling disorders (GD). GD showed none of dlPFC, dACC right AI activation, suggesting the global decrease of neural encodings of quota severity in GD patients. The dlPFC-dmPFC coupling pattern was also attenuated in the GD patients. To date, GD was often regarded as a problem elicited by overall excess risk-proneness. Our present work proposed an alternative view that GD patients have deficit in flexible modulation of risk attitude under quota.