The NEW time schedule for
"International symposium on Prediction and Decision Making"

*Doctor Geoffrey Schoenbaum's talk 9:40-10:10 on October 13 has been canceled due to the suspension of business operations in the United States federal government.

Day1: October 13, 2013

9:00-9:30	Registration
9:30-9:40	Opening Remarks Kenji Doya

Session1: Model-based decision making and its neuronal mechanisms

9:40-10:10	Kenji Doya
10:10-10:40	Daeyeol Lee
10:40-11:00	Coffee Break
11:00-11:30	Masamichi Sakagami
11:30-12:00	Daphna Shohamy
12:00-13:00	Lunch
13:00-14:30	Poster session

Session2: Nigro-striatal circuit for decision making

14:30-15:00	Paul Phillips
15:00-15:30	Fumino Fujiyama
15:30-16:00	Hitoshi Okamoto
16:00-16:20	Coffee Break
16:20-16:50	Takatoshi Hikida
16:50-17:20	Fatuel Tecuapetla
17:30-19:30	Reception

Day2: October 14, 2013

9:00-9:30 Registration

Session3: Social decision making

9:30-10:00 Karl Sigmund

10:00-10:30 Hidehiko Takahashi

10:30-10:50 Coffee Break

10:50-11:20 Masaki Isoda

11:20-11:50 Hiroyuki Nakahara

11:50-13:00 Lunch

13:00-14:30 Poster session

Session4: Uncertainty and Confidence

14:30-15:00 Adam Kepecs

15:00-15:30 Yutaka Komura

15:30-16:00 Masaaki Ogawa

16:00-16:20 Closing Remarks

Geoffrey Schoenbaum

NIDA-Intramural Research Program

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Day 1: October 13th 9：40-

How do you estimate you will like them apples? The role of the orbitofrontal cortex in imagining outcomes

The orbitofrontal cortex is often critical to value-guided behavior and learning. I will review evidence from inactivation and single-unit recording studies that suggests this is only true when the underlying value must be derived or estimated through a knowledge of the underlying associative structure of the environment and not when it can be pre-computed or cached based on direct prior experience.

Kenji Doya

Okinawa Institute of Science and Technology

Day 1: October 13th 9：40-

Prediction, confidence, and patience

Decision making requires assessment of the values resulting from possible action candidates. While this can be done in a model-free manner, simply by updating a scalar value for each action in each state, many of our decisions are model-based, involving explicit prediction or mental simulation of what will happen, when, and how probably. Which brain areas support such mental simulation? What neural circuit mechanism realizes it? What is the control mechanism for harnessing it (e.g., to avoiding delusion)? Here we report our efforts toward answering these critical questions.

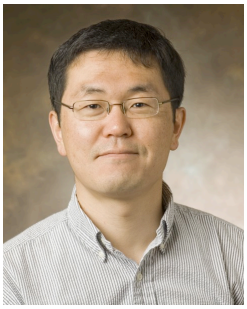
First, we performed a functional MRI experiment in which subjects performed simple but non-trivial task that requires multi-step prediction of the cursor movements on the screen after key presses. Analysis of the brain activity during the planning period before finger motion showed that different brain areas are involved in such planning depending on the degree of the learning of internal models.

In order to understand the neural circuit mechanism of mental simulation, we are performing two-photon imaging of the mouse cortex during a task that required prediction of the position of a moving sound source. Our preliminary data shows some of the parietal cortex neurons are involved in such predictions.

An important issue in predicting the future is how far ahead one should take into account. Our series of recording and manipulation experiments with rats and mice suggests that the serotonergic projection from the dorsal raphe nucleus plays a key role in the regulation of the patience of an animal, and that the effect of serotonin is dependent on the confidence of the animal.

Daeyeol Lee

Yale University



Day 1: October 13th 10:10-

Cortical substrates of dynamic social interactions

During repeated social interactions, decision makers adjust their strategies incrementally to approximate optimal strategies, often using simple, model-free reinforcement learning algorithms. In addition, such simple learning algorithms can be complemented by high-order strategies to evade the exploitation of their opponents. Here, we analyzed the choice behaviors of rhesus monkeys performing a biased matching pennies game against a computer. We found that the prediction of simple reinforcement learning was systematically violated following specific sequences of choices and outcomes that prompted the computer opponent's exploitative algorithm. Thus, monkeys used high-order strategies to counter the opponent's strategies. The information about specific choiceoutcome conjunctions constituting such high-order strategies were found most frequently in the dorsomedial prefrontal cortex, suggesting that this area might play an important role in implementing high-order strategies during dynamic social interactions.

Masamichi Sakagami

Tamagawa University

Day 1: October 13th 11：00-

Reward Inference by Primate Prefrontal and Striatal Neurons

The brain contains multiple yet distinct systems involved in reward prediction. To understand the nature of these processes, we recorded single-unit activity from the lateral prefrontal cortex (LPFC) and the striatum in monkeys performing a reward inference task using an asymmetric reward schedule. We found that prefrontal neurons could predict the reward value of a stimulus using transitive inference even when the monkeys had not yet learned the stimulus-reward association directly, while striatal neurons did not show such ability. However, striatal neurons were able to infer the reward value of a stimulus in a pair once directly experiencing the alternative with reward. Our results suggest dissociable reward inference functions in both of these areas, i.e., the LPFC was involved in transitive reward inference and the striatum in exclusive reward inference. Moreover, the striatum showed more complex functions than previously surmised for model-free learning.

Daphna Shohamy

Columbia University

Day 1: October 13th 11:30-

Building and using flexible memories: Neural and cognitive mechanisms of memory-guided decisions

Every day people make new choices between alternatives that they have never directly experienced. Yet, such decisions are often made rapidly and confidently. Here I will review recent work from my lab that shows that the hippocampus, traditionally known for its role in building long-term declarative memories, enables past experience to bias values and to guide decisions. Using functional brain imaging in humans, we found that giving people monetary rewards led to activation of a network of memories, spreading the positive value of reward to non-rewarded items stored in memory. This value-based decision bias is predicted by activity in the hippocampus during learning. Moreover, we show that different people differ in their tendency to use memories to guide decisions, and this variability is related to the strength of connectivity between the hippocampus and the vmPFC at rest. Together, these findings explain how biased choices emerge automatically from the mechanisms by which the brain builds memories in the hippocampus. Our findings further demonstrate a role for a broad network between the hippocampus, the vmPFC and the striatum in supporting such behavior.

Paul Phillips

University of Washington

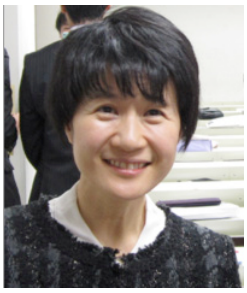
Day 1: October 13th 14:30-

What is the role of dopamine in economic decision making?

It has long been known from classic neuropharmacological studies that dopamine is pivotal to reward processing. Based upon in vivo neurophysiological evidence, it is proposed that dopamine updates the reward-predictive weights of environmental stimuli through reinforcement learning and transmits economic information about these stimuli. Consequently, dopamine transmission in the mesolimbic pathway is considered to be one of the most influential neurotransmitters in economic decision making. I will describe a series of studies designed to refine our understanding of the specific role that dopamine plays during simple (two-choice) economic decision making. This work uses a number of behavioral manipulations combined with sub-second time-resolved neurochemical measurements of dopamine as well as interference of dopamine transmission. Specifically, the work addresses what information is encoded in phasic mesolimbic dopamine release and how this information influences decisions in real time. The conclusion of these studies is that dopamine plays a nuanced role in decision making which I will describe in the seminar.

Fumino Fujiyama

Doshisya University Graduate School of Brain Science



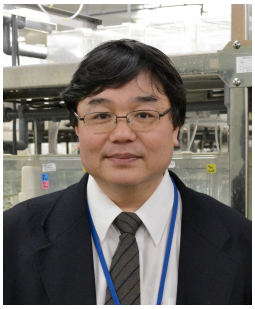
Day 1: October 13th 15：00-

New morphological findings of nigro-striatal circuit.

In addition to the two segregated striatofugal groups (direct and indirect pathways), the neostriatum possesses a mosaic organization composed of striosome/patch and matrix compartments. In the reinforcement learning, the neostriatal neurons in the compartments have been presumed to serve as unique functions due to the influence of dopaminergic neurons. Here, we analyzed the input/output organization between the striatal neurons and dopaminergic neurons using the recombinant Sindbis virus vector, preproenkephalin/GFP BAC transgenic mouse and vesicular glutamate transporters. Different from the previous report, the single dopaminergic neurons innervated both the compartments. Furthermore, we have revealed common and different pathways originating the striatal compartments. These results suggest that striosome neurons play more important role in the formation of reward-related signals of dopaminergic neurons than matrix neurons do. With the previous studies in the reinforcement learning theory, these direct and indirect striosomal pathways together with nigrostriatal dopaminergic neurons may help striosome neurons to acquire the state-value function.

Hitoshi Okamoto

RIKEN Brain Science Institute



Day 1: October 13th 15：30-

The habenula acts as the switchboard in fear response and aggression

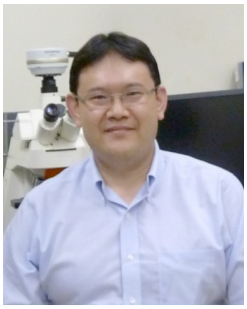
The habenula (Hb) is an evolutionarily conserved diencephalic structure that acts as a relay nucleus connecting the limbic forebrain with the brain stem monoaminergic systems. In mammals, the Hb is subdivided into medial and lateral regions (MHb and LHb, respectively). We recently discovered that the dorsal and ventral Hb (dHb and vHb) of zebrafish correspond respectively to the MHb and LHb of mammals. In mammals, the LHb is activated by receiving the unpredictable aversive stimuli, and represses the activity of dopaminergic and serotonergic neurons. We established the in transgenic zebrafish in which the neural transmission from the vHb is specifically inhibited. The active avoidance learning was specifically impaired, demonstrating the essential role of the vHb in the aversive learning.

The functions of the MHb in mammals have long remained ambiguous. Recently, we demonstrated in zebrafish that the lateral subnuclei of the dorsal habenula (dHbl) are asymmetrically connected with the dorsal and intermediate parts of the interpeduncular nucleus (d/iIPN). This pathway further projects to the region containing the equivalents of the dorsal raphe, the periaqueductal gray, and the dorsal tegmental nuclei. Specific silencing of the dHbl-d/iIPN pathway rendered animals extraordinarily prone to freeze in response to conditioned fear stimuli, while the control fish showed only flight behaviors, implicating this pathway in experience-dependent reevaluation of danger during the fear conditioning trials.

We wondered whether the same capacity of this pathway is utilized in case of fighting between two males which have become territorial after isolation, because constant reevaluation of the opponent's strength is necessary during fight until the dominant winner and subordinate loser is ultimately determined. In wild-type zebrafish, it is reported that previous winning experience remarkably increases the probability of winning a subsequent contest. However, this experience-dependent behavior was not found in dHbL-silenced fish. Most of the dHbL-silenced winners of the first interaction lost the second interaction against a naive dHbL-silenced fish, suggesting the role of the dHbl-d/iIPN pathway in accumulation of confidence upon victory in fight.

Takatoshi Hikida

Graduate School of Medicine and Faculty of Medicine Kyoto University



Day 1: October 13th 16：20-

Distinct roles of direct and indirect pathways in the nucleus accumbens to reward and aversive behavior.

The nucleus accumbens plays a critical role in reward and aversive learning and decision making. The inputs of the nucleus accumbens are transmitted through two parallel direct and indirect pathways and controlled by dopamine transmitter. To explore how the associative learning behavior is controlled in the nucleus accumbens, we developed a reversible neurotransmission blocking (RNB) technique, in which transmission-blocking tetanus toxin was specifically expressed in the direct striatonigral or the indirect striatopallidal pathway and, in turn, blocked each pathway in a doxycycline-dependent manner. We have revealed the distinct role of the two striatal pathways: the direct pathway critical for reward-based learning and the indirect pathway for aversive behavior and flexibility of learning. We also addressed the regulatory mechanisms of the nucleus accumbens circuit, suggesting the dynamic shift of neural plasticity is essential for reward and aversive behavior.

Fatuel Tecuapetla

Neurobiology of Action lab
Champalimaud Neuroscience Program

Day 1: October 13th 16 : 50-

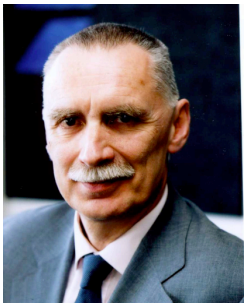
Role of basal ganglia pathways in initiation and performance of action sequences

The basal ganglia have been implicated in the control of action sequences. The striatum, the main input to the basal ganglia is composed of two projection pathways, the striatonigral and the striatopallidal projections. I will present data investigating the role of these pathways during the initiation and performance of self-paced action sequences by manipulating their activity using optogenetics.
We trained mice to develop action sequences (lever press) and using channelrhodopsin 2 (Chr2) or Archaerhodopsin (ArchT 3.0) we manipulate the firing of the striatal neurons optically during or after the initiation of action sequences. The specificity of the ChR2 or the ArchT3.0 manipulations in the striatonigral or striatopallidal pathway was obtained by striatal injections of adeno-associated virus with Cre-dependent opsin expression into D1-Cre and D2-Cre (expressing Cre recombinase in D1 or D2 dopamine receptors expressing neurons, respectively).

Our current data shows that both the striatonigral and the striaopalidal subcircuits are necessary for the initiation of the action sequences while the activity of these two pathways is differentially involved during the performance. Low over-activation of the striatonigral pathway induces more repetitions of the action (lever press) while high over-activation of the same pathway induces a pause in the performance. On the other hand over activation of the indirect pathways generates a switch in the performance of the action sequences. These data is consistent with models proposing the simultaneous/concurrent activation of the basal ganglia pathways during action initiation.

Karl Sigmund

Mathematics University of Vienna



Day 2: October 14th 9 : 30-

The evolution of sanctioning institutions: a game theoretical approach to the social contract

A vast amount of empirical and theoretical research on public good games indicates that the threat of punishment can curb free-riding in human groups engaged in joint enterprises. Since punishment is often costly, however, this raises an issue of second order free-riding: indeed, the sanctioning system itself is a common good which can be exploited. Most investigations, so far, considered peer punishment: players could impose fines on those who exploited them, at a cost to themselves. Only a minority considered so-called pool punishment. In this scenario, players contribute to a punishment pool before engaging in the joint enterprise, and without knowing who the free-riders will be. Theoretical investigations have shown that peer punishment is more efficient, but pool punishment more stable. Social learning, i.e., the preferential imitation of successful strategies, should lead to pool punishment if sanctions are also imposed on second-order free-riders, but to peer punishment if they are not. Here I describe an economic experiment (the Mutual Aid game) which tests this prediction. Pool punishment only emerges if second order free riders are punished, but that peer punishment is more stable than expected. Basically, experiment and theory show that social learning can lead to a spontaneously emerging social contract, based on a sanctioning institution to overcome the free rider problem.

Hidehiko Takahashi

Department of Psychiatry, Kyoto University Graduate School of Medicine

Day 2: October 14th 10：00-

Molecular imaging of emotional decision making in human

We sometimes make boundedly rational decision-makings (altruistic behavior, moral judgment gamble etc.), which is not accounted for by normative economic theories (e.g. expected utility theory) that assume that individuals are rational decision makers and have purely self-regarding preferences. These boundedly rational decision-makings are highly influenced by emotions.

Over the last decade, neuroeconomics studies utilizing neurophysiology methods (fMRI or EEG) has flourished, revealing the neural basis of boundedly rational decision-making that violates normative theory. The next question is how modulatory neurotransmission is involved in these central processes. Here I focused on recent efforts to understand how central monoamine transmission is related to this topic.

Our approach may contribute to a better understanding of the role of neurotransmitters in emotional and boundedly rational decision-making in human. At the same time, understanding the molecular mechanism of extreme or impaired decision-making can contribute to the assessment and prevention of neuropsychiatric disorders.

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Masaki Isoda

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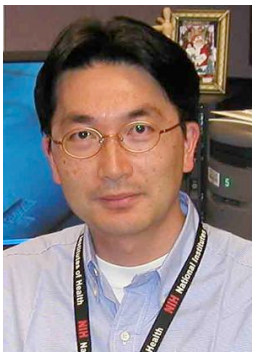

Day 2: October 14th 10：50-

Social action monitoring: from genes to physiology and behavior

For successful social interactions, one needs to monitor the behavior of other individuals, as it can provide an important clue to understanding their mental states, such as their beliefs, desires and intentions. The medial frontal cortex (MFC) has been consistently activated when people keep track of their own performance. But recent studies suggest that the MFC also participates in the monitoring of others' behavior in social settings. We carried out single-unit recording in neurotypical monkeys using a role-reversal choice task and found that the MFC contains many cells that selectively encode others' actions or detect others' erroneous actions. Notably, these cells were virtually absent in the MFC of a monkey exhibiting a social monitoring impairment. Moreover, this monkey had abnormalities in candidate genes that are linked to neuropsychiatric disorders in humans. These data support the hypothesis that the MFC plays a major role in social action monitoring. Our findings may explain the genetic basis of individual differences in social cognitive abilities.

Hiroyuki Nakahara

RIKEN Brain Science Institute

Day 2: October 14th 11：20-

Primitives for learning to predict the mind of others

Learning and predicting the minds of others is critical for social cognition. Combining behavior, fMRI and modeling, I will show evidence for two of the computational primitives, namely learning signals to simulate others' value-based decision-making: a reward prediction error, generated by simulating others' valuation process by direct recruitment of one's own process and encoded in ventromedial prefrontal cortex, and an action prediction error, generated by combining the simulation with observation of the other's choices and encoded in dorsolateral/dorsomedial prefrontal cortex. If time allows, I will also present our preliminary results on another important proposition in social cognition, which is that we change our decisions by knowing the consequence to others. We examined primitives for processing to modify one's own decisions due to reward of others.

Adam Kepecs

Cold Spring Harbor Laboratory

Day 2: October 14th 14：30-

From metacognition to statistics: prefrontal circuits behind confidence

Decision confidence is a forecast about the correctness of one's decision. It is often regarded as a higher-order function of the brain requiring a capacity for metacognition that may be unique to humans. If confidence manifests itself to us as a feeling, how can then one identify it amongst the brain's electrical signals in an animal?

We tackle this issue by using mathematical models to gain traction on the problem of confidence, allowing us to identify neural correlates and mechanisms. I will present a normative statistical theory that enables us to establish that human self-reports of confidence are based on a computation of statistical confidence. Next, I will discuss computational algorithms that can be used to estimate confidence and decision tasks that we developed to behaviorally read out this estimate in humans and rats. Finally, I will discuss the neural basis of decision confidence and specifically the role of the orbitofrontal cortex.

Yutaka Komura

National Institute of Advanced Industrial Science and Technology

Day 2: October 14th 15：00-

Neural and explanatory correlates of decision certainty in subcortical signals

We can adjust a wide range of our decisions, based on the degrees of certainty or uncertainty. However, less is known about how the brain estimates and uses decision (un)certainty. For several years, it has been discovered that neuronal responses in frontal and parietal cortices represented decision (un)certainty. Recently, we recorded single-unit activities from the monkeys performing a binary decision task and an opt-out task, and found out the neural correlates of decision certainty in the pulvinar, a subcortical region. Moreover, temporal inactivation of the pulvinar had a specific effect on the opt-out performances. These pulvinar responses and monkeys' performances under normal and inactivated states were explained well by a theoretical model of confidence. We would like to discuss the relationships between cortical and subcortical signals of decision certainty.

Masaaki Ogawa

National Institute for Physiological Sciences

Day 2: October 14th 15：30-

Tracking salience acquired through associative learning, not risk, in the orbitofrontal neurons.

Decision-making is impacted by reward uncertainty and risk (i.e. variance). Activity in the orbitofrontal cortex, an area implicated in decision-making, has been shown to covary with these quantities. However, this activity could reflect the heightened salience of situations in which multiple outcomes -reward and reward omission - are expected. To resolve these accounts, rats were trained in a simple odor-cued response task, in which 4 different odor cues were associated with 4 different probabilities of reward, 100, 67, 33 and 0%, respectively. Consistent with prior reports, some orbitofrontal neurons (36%) fired differently in anticipation of uncertain (33% and 67%) versus certain reward (100% and 0%). However, over 90% of these neurons also
fired differently prior to 100% versus 0% reward (or baseline), or prior to 33% versus 67% reward. These responses are inconsistent with risk, but fit well with the representation of acquired salience linked to the sum of cue-outcome and cue-no-outcome associative strengths. Thus, these results suggest a novel mechanism whereby the orbitofrontal cortex might regulate learning and behavior.