Second Symposium on Biology of Decision-Making

May 10-11, 2012, Paris, France

Organizing committee

Thomas Boraud
(Institut des Neurosciences de Bordeaux, Université Victor Segalen – Bordeaux 2 / Centre National de la Recherche Scientifique)

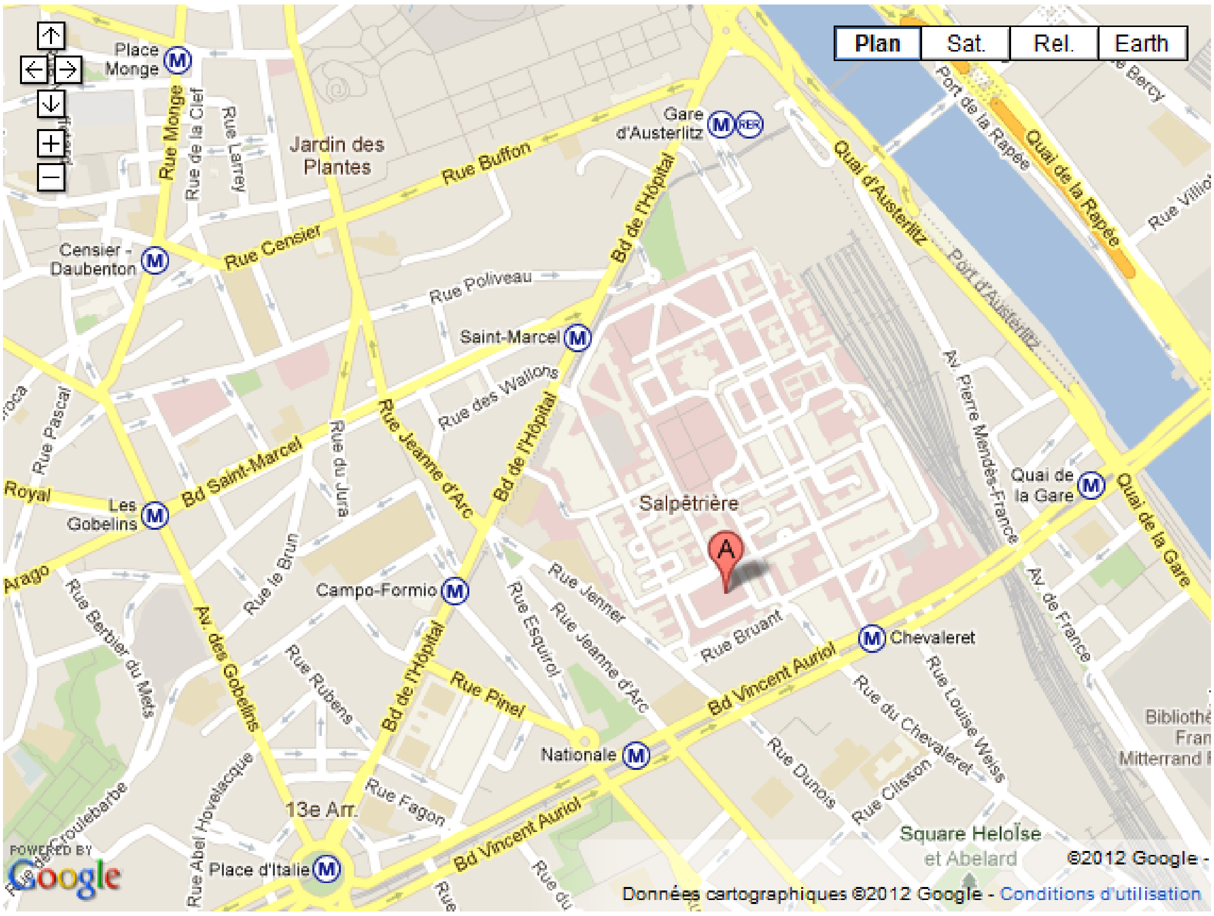
Sacha Bourgeois-Gironde
(Aix-Marseille School of Economics, Université d'Aix-Marseille / Institut Jean Nicod)

Mehdi Khamassi
(Institut des Systèmes Intelligents et de Robotique, Université Pierre et Marie Curie – Paris 6 / Centre National de la Recherche Scientifique)

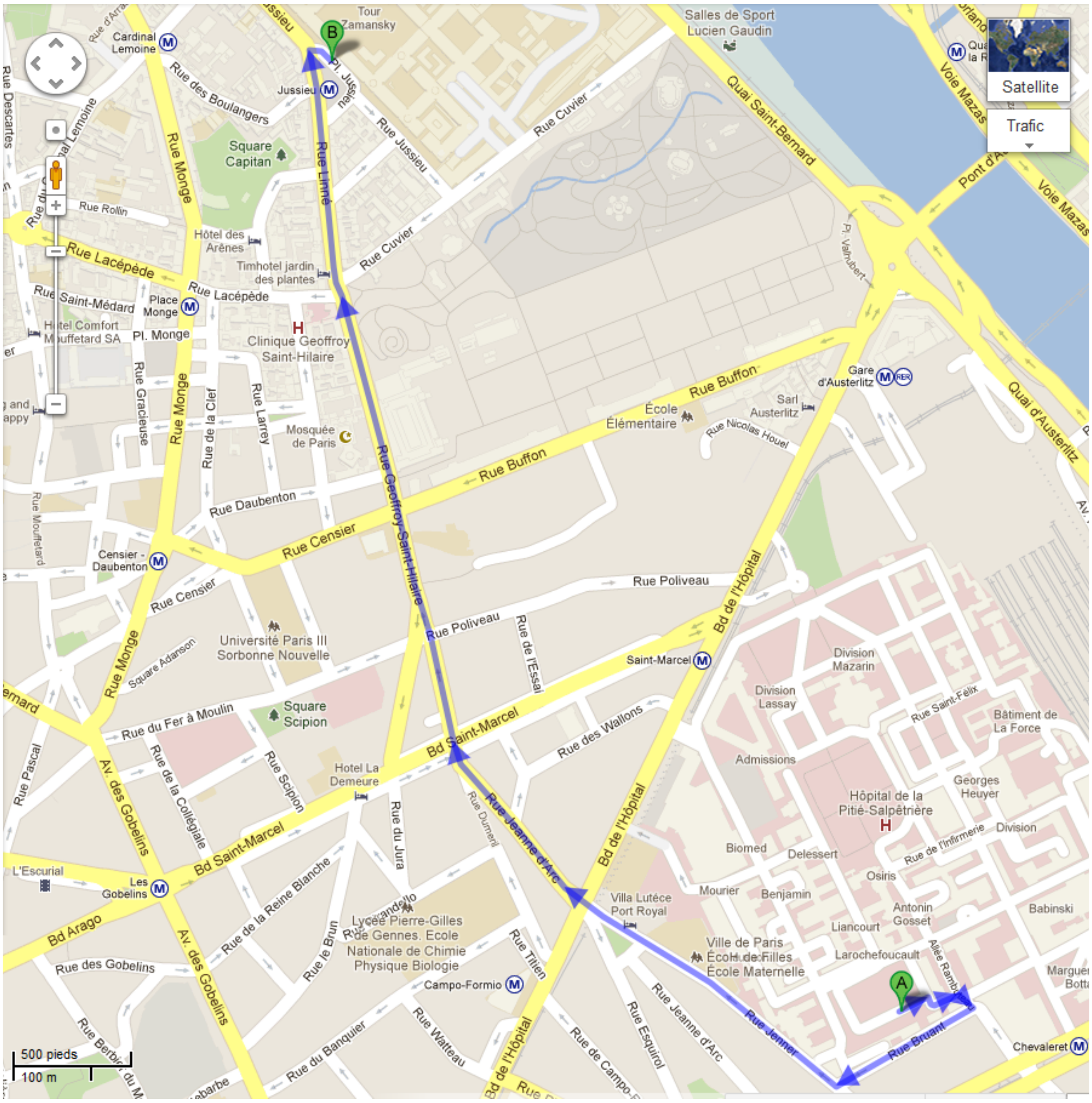
Mathias Pessiglione
(Centre de Recherche de l'Institut du Cerveau et de la Moelle / Institut National de la Santé et de la Recherche Médicale)

Locations

Lectures and posters: *Amphithéâtre* of the Institut du Cerveau et de la Moelle Epinière (ICM), Hôpital Pitié-Salpêtrière, 47 boulevard de l'hôpital – 75013 Paris **(Location A on the two maps)**



Social event (May 10 evening): 24th floor of Tour Zamansky, on Université Pierre et Marie Curie (UPMC) campus, 4 place Jussieu – 75005 Paris **(Location B on the map)**



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Thursday 10 May 2012

***Amphithéâtre* of the *Institut* du *Cerveau* et de la *Moelle* Epinière (ICM).**
Hôpital Pitié-Salpêtrière, 47 boulevard de l'hôpital - 75013 Paris

Morning - Neuro-Physiology Session

9:00-9:30	Registration
9:30-9:40	Welcome word
9:40-10:20	**A. David Redish.** Differences in information processing between decision-making systems.
10:20-11:00	**Brian Lau.** The amygdala combines space and value to guide attentional selection.
	Coffee break & Poster session
11:40-12:20	**Francesca Sargolini.** Learning to dissociate spatial trajectories: different contributions of the dorsomedial and the dorsolateral striatum.
12:20-13:00	**Thomas Boraud.** Why is the striatum silent?
	Lunch time & Poster session

Afternoon - Neuro-Computations Session

14:30-15:30	**Plenary talk: Kenji Doya.** Multiple Strategies for Decision Making.
15:30-16:10	**Benoît Girard.** Interactions of model-based & model-free learning processes in rodent navigation.
16:10-16:50	**Boris Gutkin.** Drug Effects in Dopaminergic circuits spiral addicts to a cognitive/behavioral conflict: what they say is NOT what they do.
	Coffee break & Poster session
17:30-18:10	**Kevin Gurney.** Modeling the basal ganglia at multiple levels of description: from spikes to rate codes algorithms and robots.
18:10-18:50	**Arthur Leblois.** Dopamine in songbirds: modulation of basal ganglia activity and regulation of behavioral variability.

Social event **-** Buffet with panoramic view on Paris, from the 24th floor of Tour Zamansky, on Université Pierre et Marie Curie (UPMC) campus.

Friday 11 May 2012

***Amphithéâtre* of the *Institut* du *Cerveau* et de la *Moelle* Epinière (ICM).**
Hôpital Pitié-Salpêtrière, 47 boulevard de l'hôpital - 75013 Paris

Morning - Neuro-Systems Session

9:00-9:40 **Tali Sharot.** The good news bad news effect in belief updating.
9:40-10:20 **Todd Hare.** The neural mechanisms of self-control in value-based choice.
10:20-11:00 **Philippe Tobler.** Value representations in midbrain and striatum.

Coffee break & Poster session

11:40-12:20 **Mathias Pessiglione.** How to resist temptation: cognitive control and episodic simulation.
12:20-13:00 **Etienne Koechlin.** Control, learning and exploration: human adaptive behavior and decision-making.

Lunch time & Poster session

Afternoon - Neuro-Economics Session

14:30-15:10 **Marie-Claire Villeval.** Audience effects on two types of pro-social behavior.
15:10-15:50 **Itzhak Aharon.** The Neuroscience and Psychophysiology of Experience-Based Decisions.
15:50-16:30 **Guillaume Hollard.** Do non-strategic players really exist? Evidence from experimental games involving step reasoning.

Coffee break & Poster session

17:10-17:50 **Eyal Winter.** Emotions, Mental Equilibrium and Mind Reading.
17:50-18:30 **Sacha Bourgeois-Gironde, Juko Ando, Chizuru Shikishima, Mitsu Okada.** How deep are decision-theoretical paradoxes biologically wired?
18:30-18:40 *Closing word.*

ABSTRACTS

Thursday 10 May, morning - Neuro-Physiology Session

A. David Redish (University of Minnesota, USA)
"Differences in information processing between decision-making systems"

When rats come to spatial choice points, they sometimes pause and look back-and-forth, a phenomenon identified in the 1930s as "vicarious trial and error" (VTE). I will present our work on information processing during VTE events and non-VTE events that suggests that VTE is evidence of decision-making through deliberative/flexible/search-based processes, while non-VTE is evidence of decision-making through slowly-learned situation-action or action-action sequences. If there is time, I will present our new neuroeconomic data on the presence of VTE under different valuation conditions.

Brian Lau (CRICM Paris / Columbia University, USA)
"The amygdala combines space and value to guide attentional selection"

Seeing a salient object can trigger both emotional and cognitive responses. Scientists commonly assume that the amygdala mediates emotional responses but not cognitive ones such as the top-down direction of attention to object locations. I will present data that suggest that amygdala activity is in fact appropriate for directing attention towards motivationally relevant locations, encoding information about both the motivational value and location of visual cues. Moreover, neural responses were correlated with trial-to-trial fluctuations in the allocation of spatial attention. These results highlight a novel role for the amygdala in directing attention towards motivationally significant stimuli. Amygdala dysfunction may therefore contribute to symptoms of psychiatric disorders such as schizophrenia and autism, where patients have difficulties directing attention according to the emotional relevance of stimuli.

Francesca Sargolini (Université de Provence - Aix-Marseille 1, France)
"Learning to dissociate spatial trajectories: different contributions of the dorsomedial and the dorsolateral striatum"

Several studies on instrumental conditioning suggest the existence of two independent decision-making processes, one inflexible and dependent upon DLS activity, the other based on flexible goal-oriented responses and mediated by the DMS. However, very few studies have investigated whether a similar dissociation exists in more complex behaviors, such as spatial learning. The present study examined the role of the two structures in this behavior 1) by analyzing the effects of excitotoxic DMS and DLS lesions and 2) by comparing DMS and DLS neuronal activity, during the acquisition and extinction of a spatial alternation behavior in a continuous alternation T-maze task, originally employed to characterize hippocampal place cells activity.
We first demonstrated that DMS and DLS lesions have opposite effects, the first impairing and the second improving rats performance during learning and extinction. Secondly, neurons from the two brain areas displayed different task-related responses. In particular, DMS provides a signal necessary to dissociate different spatial trajectories, whereas the DLS preferentially activate for egocentric movements and reward delivery, irrespective of left/right goal position.
Taken together, these results indicate that the DMS and DLS may support in different ways the acquisition and performance of a spatial goal-directed behaviour, and suggest that DMS- and DLS-mediated learning strategies develop in parallel and compete for the control of the behavioral response during learning.

Thomas Boraud (CNRS Université Victor Segalen - Bordeaux 2, France)
"Why is the striatum silent?"

Thursday 10 May, afternoon - Neuro-Computations Session

Kenji Doya (Okinawa Institute of Science and Technology, Japon; Invited Professor at Université Pierre et Marie Curie, Paris)
"Multiple Strategies for Decision Making"

The theory of reinforcement learning prescribes two major strategies of decision making: model-based and model-free. The dichotomy has been helpful in searching for the computational bases for goal-directed and habitual behaviors, conscious and unconscious actions, and so forth (e.g., Daw et al., 2005). Both model-based and model-free strategies, however, have several different algorithms for implementation and we are assessing which of them are used in what stage of learning, and by what neural mechanisms.
In the analysis of rats' binary choice sequences under probabilistic reward, we had earlier showed that action value-based models predicted rats' choices better than higher-order Markov models (Ito & Doya, 2009). However, recent analysis of a new set of data revealed that finite state-based models predict rats' choices better than action value-based models. Analysis of striatal neural firing revealed both action value-coding and finite state-coding neurons in the dorsomedial striatum.
In a human fMRI experiment requiring multiple steps of actions to the goal, we found the evidence of model-based action planning in the intermediate stage of learning, when the activities were seen in not only the cortical areas (parietal, premotor, prefrontal), but also the anterior basal ganglia and the lateral cerebellum. Behaviors in both early and late stages of learning can be considered as model-free, but the performance as well as the brain activation during the two stages were largely different.
The results suggest the need for considering at least two different sub-types of model-free decision making, namely, value-based and procedure-based. The neural implementation of model-based decision making may not just involve the prefrontal cortex, but also the basal ganglia and the cerebellum (Doya, 1999).

Benoît Girard (CNRS Université Pierre et Marie Curie - Paris 6, France)
"Interactions of model-based & model-free learning processes in rodent navigation"

Kevin Gurney (University of Sheffield, UK)
"Modeling the basal ganglia at multiple levels of description: from spikes to rate codes algorithms and robots"

Computational modelling can be a powerful tool for developing our understanding of the basal ganglia, but how should we go about doing this? Starting from a functional hypothesis - that the basal ganglia play a critical role in mediating action selection - we have developed models at several levels of description: from spiking circuits, through rate-coded (neural population) models, to algorithms and autonomous robots. I will argue that there is a rational for all these levels of description and explore their interrelationship.

Boris Gutkin (CNRS Ecole Normale Supérieure, France)
"Drug Effects in Dopaminergic circuits spiral addicts to a cognitive/behavioral conflict: what they say is NOT what they do"

Long-term addicts find themselves powerless to resist drugs, despite knowing that drug-taking may be a harmful course of action, and an explicit motivation to quit. We provide a unified computational theory for this inconsistency by showing how addictive drugs gradually produce a motivational bias toward drug-seeking at low-level habitual decision processes, despite the low abstract cognitive values. This pathology emerges within the hierarchical reinforcement learning framework when chronic drug-exposure pharmacologically hijacks the dopaminergic spirals that cascade reinforcement signal down the ventro-dorsal cortico-striatal hierarchy. Additionally our framework addresses the gradual insensitivity of drug-seeking to drug-associated punishments. Finally, it accounts for the delayed development of cue-elicited dopamine efflux in addicts' dorsal striatum, as well as some other behavioral and neurobiological aspects of addiction. Time permitting we will also discuss specific pharmacological points-of-entry within the dopamine-associated circuitry that imply the addictive potential for various drugs.

Arthur Leblois (Université Paris Descartes, France)
"Dopamine in songbirds: modulation of basal ganglia activity and regulation of behavioral variability"

Cortico–basal ganglia (BG) circuits are thought to promote the acquisition of motor skills through reinforcement learning. In songbirds, a specialized portion of the BG is responsible for song learning and plasticity. This circuit generates song variability that underlies vocal experimentation in young birds and modulates song variability depending on the social context in adult birds. When male birds sing in the presence of a female, a social context associated with decreased BG-induced song variability, the extracellular dopamine (DA) level is increased in the BG. I will present our results showing that DA triggers song variability changes with social context through its action in the BG. Indeed, DA delivered in the BG, acting through D1 receptors, weakens the output signal of the avian cortico-BG circuit. In behaving birds, interfering with D1 receptor transmission in Area X abolishes social context-related changes in song spectral variability, while other social context modulated song characteristic remain unaffected.

Friday 11 May, morning - Neuro-Systems Session

Tali Sharot (Department of Cognitive, Perceptual and Brain Sciences, UCL, UK)
"The good news bad news effect in belief updating"

Todd Hare (University of Zurich, Switzerland)
"The neural mechanisms of self-control in value-based choice"

Self-control is an important component of dietary choices and for some individuals it is a critical factor in maintaining a healthy body weight. I will present data that are designed to test a two-part hypothesis: 1) the overall value of a reward predicting stimulus is represented in ventral medial prefrontal cortex (vmPFC) regardless of self-control level during decision making, and 2) self-control is implemented by means of interactions between the dorsolateral prefrontal cortex (dlPFC) and vmPFC.
We used a combination of functional magnetic resonance imaging (fMRI) and electroencephalography (EEG) to compare neural activity during successful self-control (SSC) and non-self-control (NSC) choices over food and monetary rewards. In both cases, the overall value of the reward was reflected in the activity of vmPFC and the timing was similar for both SSC and NSC decisions. In other words, the vmPFC represented the overall value the rewards in a manner consistent part one of the hypothesis.
To determine if dlPFC played a role in self-control choices, we compared SSC and NSC decisions. There was greater activity in dlPFC for SSC compared to NSC. Furthermore, we found using dynamic causal modeling (DCM) of the fMRI data that this region of dlPFC showed increased signaling to the vmPFC during self-control choices. Moreover, these DCM parameters could be used to explain individual differences in self-control behavior across subjects. We also used EEG to confirm that the timing of interactions between dlPFC and vmPFC at the millisecond level is consistent with dlPFC signaling to vmPFC at the time of choice.

In summary, our data support both aspects of the hypothesis. First, regardless of self-control level, the overall value of a reward predicting stimulus is represented in the activity levels of vmPFC. Second, dlPFC can modulate of value computations in the vmPFC.

Philippe Tobler (University of Zurich, Switzerland)
"Value representations in midbrain and striatum"

The dopaminergic midbrain heavily innervates the striatum, which in turn also receives sensory, affective and motor inputs from further regions, both cortical and subcortical. The present talk gives an overview of the value signals originating in the dopaminergic midbrain (single cell recording in the non-human primate), which are closely mirrored by striatal activations (functional neuroimaging in humans). Both represent reward probability, magnitude and risk, are activated by a variety of reward types and show reward prediction error signals that adapt to predictions. These signals could be used by other brain regions for making value-based decisions.

Mathias Pessiglione (INSERM Institut du Cerveau et de la Moelle, France)
"How to resist temptation: cognitive control and episodic simulation"

During the last decade, a growing set of evidence has revealed that economic values are encoded in a so-called "brain valuation system" (BVS), which includes the ventral prefrontal cortex and limbic sub-cortical structures. A central issue in the recent literature is to understand how the value of rewards is discounted with the delay of delivery. This is important to prevent impulsivity in inter-temporal choices, i.e. the propensity to favor immediate rewards over long-term options. An influential theory is that dorsal prefrontal regions down-regulate the values encoded in the BVS so as to counter impulsive choices. However, the choice tasks used to assess delay discounting mostly involved abstract monetary rewards (smaller sooner versus bigger later). We argue that in more ecological situations, resisting the attraction of immediate rewards requires more than inhibitory control: it should involve mental simulation of future rewards that are not directly observable in the present environment. Simulating future episodes involves the same episodic system (in the medial temporal lobes) that is responsible for remembering past episodes. We therefore suggest that episodic structures are crucial for finding the motivation to prevent impulsive choices. We will provide some evidence supporting this hypothesis, from neuroimaging in healthy subjects and from behavioral observation in patients with temporal lobe damage.

Etienne Koechlin (CNRS Ecole Normale Supérieure, France)
"Control, learning and exploration: human adaptive behavior and decision-making"

The frontal lobes subserve decision-making and executive control, i.e. the selection and coordination of goal-directed behaviors. Current models of frontal executive function, however, do not explain human decision-making in everyday environments featuring uncertain, changing and especially open-ended situations. In this talk, I will present a computational model of frontal executive function that clarifies this issue. Using behavioral experiments, I will show that unlike others, the proposed model predicts human decisions and their variations across individuals in naturalistic situations. The model constitutes a biologically plausible algorithm that approximates optimal statistical models based on Dirichlet process mixture by combining reinforcement learning, online limited bayesian inferences and hypothesis-testing for arbitrating between: (1) staying with an ongoing behavioral strategy possibly by adjusting it through reinforcement learning; (2) switching to an alternative known strategy or (3) exploring and creating a new strategy partly from mixing those stored in long-term memory. The model clarifies the distinction between the notion of procedural working-memory as a limited-capacity bayesian inference buffer and that of long-term memory as an unlimited repertoire of behavioral strategies composed of forward and backward internal models associating states, actions and outcomes. Behavioral data show that: (1) the bayesian inference buffer is limited to the concurrent monitoring of three behavioral strategies; (2) executive control has a binary structure reflecting Simon's satisficing selection processes that promotes the exploration and creation of new strategies, when facing ambiguous or unknown situations.

Preliminary fMRI data provides evidence that the bayesian inference buffer monitoring up to three concurrent strategies is implemented in the anterior prefrontal cortex.

Friday 11 May, afternoon - Neuro-Economics Session

Marie-Claire Villeval (CNRS Université Claude Bernard - Lyon 1, France)
"Audience effects on two types of pro-social behavior"

We use functional magnetic resonance imaging to investigate the neural correlates of choices taken in two types of situations where moral and monetary rewards are at odds: 1) people can incur a monetary loss to allow a donation to a positively evaluated organization (i.e. costly donation to a charity), and 2) can refuse to earn money in order to avoid a monetary transfer to a negatively evaluated organization (costly opposition). By systematically varying the price of the transfer and the degree of visibility of decisions, we show that for these two types of decisions, moral and monetary rewards are weighted and evaluated by different interconnected brain regions, depending on whether social image represents an issue or not. Monetary benefits deriving from not opposing a negatively evaluated association are computed in the lateral OFC, region related to the evaluation of changing contingencies and punishers, while avoiding a donation to preserve monetary payoffs recruits the median OFC, region connected to the appraisal of the reward value of reinforcers (e.g. money). Activations in these regions are higher when these types of selfish decisions are taken in private, suggesting that two different mechanisms are in place for the two conditions.

Itzhak Aharon (IDC Herzliya, Israel)
"The Neuroscience and Psychophysiology of Experience-Based Decisions"

Experience-based decisions can be defined as decisions emanating from direct or vicarious reinforcements that were received in the past. The study of experience-based decisions has recently revealed some robust regularities that differ from how people make decisions based on descriptions.

We suggest that while frontal activation may be used as an index of decision processes, there are still important and unaddressed gaps in brain and behavioral patterns in experience-based decisions. In my talk I'll discuss three these gaps.

Guillaume Hollard (CNRS, Economics Paris School, France)
« Do non-strategic players really exist? Evidence from experimental games involving step reasoning »

It has long been observed that players in experimental games differ in their strategic ability. In particular, some players seem to completely lack any strategic ability. These non-strategic players have however not been studied per se so far. Using a controlled experiment, we find that half of our subjects act in a non-strategic way, i.e. they do not react to important changes in the environment. We then explore the reason why these subjects are performing so poorly. Our design allows us to rule out several widespread explanations like lack of attention, misconception, or insufficient incentives. Interestingly, using reaction time, we find that these subjects do pay attention to relevant changes in the environment but fail to process information in a relevant manner. This inability to act strategically is a robust finding in the sense that it transfers across games. Last, having in mind that our subjects are chess players recruited from an international tournament, we explore the reason why their strategic ability in playing chess does not transfer to laboratory games.

Eyal Winter (Hebrew University of Jerusalem / Centre for the Study of Rationality, Israel)
"Emotions, Mental Equilibrium and Mind Reading"

We introduce emotions into an equilibrium notion. In a mental equilibrium each player "selects" an emotional state which determines the player's preferences over the outcomes of the game. These preferences typically differ from the players' material preferences. The emotional states interact to play a Nash equilibrium and in addition each player's emotional state must be a best response (with respect to material preferences) to the emotional states of the others. We discuss the concept behind the definition of mental equilibrium and show that this behavioral equilibrium notion organizes quite well the results of some of the popular experiments in the experimental economics literature. Based on data collected from the British TV game "Split or Steal" we will discuss the interesting phenomenon of implicit coordination in games, and will demonstrate how the theory of Mental Equilibrium explains it.

Sacha Bourgeois-Gironde, Mitsu Okada, Chizuru Shikishima, Juko Ando (France, Japan)
"How deep are decision-theoretical paradoxes biologically wired?"

The Allais paradox is a behavioral violation of the fundamental classical decision-theoretical axiom of independence. From there three attitudes, at least, are possible: our favorite decision-theory ignores this merely this behavioral fact; our revised theory accommodates it; or, our own stance, one questions whether biologically realized decision-making systems (like the human brain) are Allaisian or classical decision-theorists. Such a question can be dealt with by various means (using smaller organisms, like insects or fish), by investigating neural mechanisms underlying decision-making in Allaisian situations, or by wondering how much this behavioral decision-theoretical anomaly is accounted for by heritability. We present our data concerning the two latter questions and two main results: i) OFC-lesioned patients are manifest classical decision-makers, complying with the independence axiom; ii) heritability is a significant parameter of Allaisian behavior, as shown by our twin-study of the Allais paradox in the Tokyo area.

LIST OF POSTERS

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1. **"A self-organized neuronal comparator"**, by G. A. Luduena and C. Gros, Goethe University Frankfurt.
2. **"Social feedback processing in East Asian and Western culture"**, Christoph W Korn , Yan Fan, Kai Zhang , Chenbo Wang , Shihui Han & Hauke R Heekeren, Freie Universität Berlin, Berlin, Germany.
3. **"Dynamics of Decision-Related Activity in Hippocampus"**, Julien Catanese, Erika Cerasti, Michael Zugaro, Alessandro Viggiano and Sidney I. Wiener, Collège de France, Laboratoire de la Perception et de l'action.
4. **"Modulatory Effect of Dopamine Receptors on Striatal Medium Spiny Neurons: A Computational Model"**, Cem Yucelgen, Berat Denizdurduran, Neslihan Serap Sengor, Istanbul Technical University, Electronics and Communication Dept., Istanbul.
5. **"To collect reward or to defend homeostasis? An integrated hypothalamo-basal ganglia circuit does both"**, Mehdi Keramati and Boris Gutkin, Group for Neural Theory, DEC, ENS, Paris.
6. **"The effect of novelty-based exploration on reinforcement learning mechanisms"**, Houillon A. (1,2,3), Lorenz R. (2), Böhmer W. (3), Heinz A. (2), Gallinat J (2), Obermayer K (1,3). 1.Berstein Center for Computational Neuroscience Berlin 2.Clinic for Psychiatry and Psychotherapy, Charité University Medicine, Berlin 3.Technical University Berlin, Neural Information Processing Group, Department of Software Engineering and Theoretical Computer Science, Berlin.
7. **"Computational Study of Neuronal Mechanisms Underlying Value-Based Decision Making"**, Enrico Cataldo (a), Douglas A. Baxter (b), John H. Byrne (b), a: Dipartimento di Fisica "E. Fermi", Università di Pisa, Italy; b: Department of Neurobiology & Anatomy, Houston, TX, USA.
8. **"Diffusion-weighted imaging tractography-based parcellation of the human dorsal prefrontal cortex and comparison with human and macaque resting state functional connectivity"**, Jérôme Sallet[1,2], Rogier B. Mars[1,2], Saad Jbabdi[2], MaryAnn P. Noonan[1,2], Jill X. O'Reilly[2],Nico Filippini[2], Steve M. Smith[2], Heidi Johansen-Berg[2], Karla L. Miller[2], & Matthew F.S. Rushworth[1,2], [1]Department of Experimental Psychology, University of Oxford, Oxford OX1 3UD, United Kingdom, [2]Centre for Functional Magnetic Resonance Imaging of the Brain, University of Oxford OX3 9DU, John Radcliffe Hospital, Oxford, United Kingdom.
9. **"Quantitative modeling of the biological substrates of the Basal Ganglia : suitable for what kind of selection ?"**, Jean Liénard, Benoît Girard, Institut des Systèmes Intelligents et de Robotique (ISIR).
10. **"Contribution of the Ventral Striatal Pathway to Decision Making"**, Selin Metin, Neslihan Serap Sengor, Istanbul Technical University, Electronics and Communication Dept.
11. **"From tug of war to horse racing: Deep brain stimulation reduces the influence of decision conflict in perceptual decision making."**, Green, Nikos1, 2, 3; Bogacz, Rafal4; Hübl, Julius5; Kühn, A., Andrea5; Heekeren, R., Hauke1, 2, 3, 1. Freie Universität Berlin, Berlin, Germany, 2. Berlin School of Mind and Brain, Humboldt Universität zu Berlin, Berlin, Germany, 3. Max Planck Institute for Human Development, Berlin, Germany, 4. University of Bristol, Bristol, United Kingdom, 5. Charité University Medicine Berlin, Berlin, Germany.
12. **"Pain Enhances Reward Seeking Behaviour and Reduces Fairness during a Bilateral Ultimatum Game"**,Alessandra Mancini1, Viviana Betti3, Maria Serena Panasiti1, Enea Francesco Pavone1,2, Salvatore Maria Aglioti1,2, 1 Psychology Department, Sapienza, University of Rome, Rome, Italy, 2Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS), Santa Lucia Foundation, Rome, Italy, 3 Institute for Advanced Biomedical Technologies, G. d'Annunzio, Univeristy of Chieti, Chieti, Italy
13. **"The neurophysiology of deceptive decision making in social interactions" ,** Panasiti MS[1], Pavone EF[1,2], Mancini A[1], Merla A[3], Aglioti SM[1,2], 1 Psychology Department, Sapienza, University of Rome, 2 IRCCS Santa Lucia Foundation, Rome, 3 I*nstitute* for *Advanced Biomedical Technologies* , Foundation G. d'Annunzio University, Chieti and Department of Neuroscience and Imaging, University of Chieti-Pescara.
14. **"How Cholinergic Innervation in Hippocampus Contributes to Early Memory Development and Attention ?"**, Alexandre Pitti, Laboratoire ETIS – UMR CNRS 8051 – Université de Cergy-Pontoise – ENSEA, France.

15. "**Encoding and Planning Sequences of Arm Gestures with a Bio-inspired Model of Cognitive Maps**", *Antoine de Rengervé, Pierre Andry and Philippe Gaussier,* ETIS UMR 8051, ENSEA, University Cergy Pontoise, CNRS, F-95000 Cergy Pontoise, France.
16. "**Multimodal integration of visual place cells and grid cells for robots navigation**", Adrien Jauffret, Nicolas Cuperlier et Philippe Gaussier, Laboratoire ETIS UMR 8051 - Université de Cergy-Pontoise.
17. "**Synchrony as a Tool to Establish Focus of Attention for Autonomous Robots**", Syed Khursheed Hasnain, Philippe Gaussier and Ghiles Mostafaoui, ETIS Laboratory UMR 8051 (ENSEA, CNRS, Cergy-Pontoise University).
18. "**Neural coding in the cortico-striatal system in a decision making task: Insights from reservoir computing**", Pierre Enel, Peter Dominey, Stem Cell And Brain Research Institute INSERM, Lyon, France.
19. "**Computational modeling of reinforcement learning in alcohol use disorder**", Sinem Balta1,2, Anne Beck3, Florian Schlagenhauf3, Michael Rapp3, Andreas Heinz2,3, Klaus Obermayer1,2, 1 Technical University Berlin, Neural Information Processing Group, Berlin, 2 Bernstein Center for Computational Neuroscience, Berlin, 3 Department of Psychiatry and Psychotherapy, Charité University Medicine, Berlin
20. "**Which Temporal Difference Learning algorithm best reproduces dopamine activity in a multi-choice task ?**", Jean Bellot, Olivier Sigaud, and Mehdi Khamassi, ISIR UPMC
21. "**A biologically inspired meta-control navigation system for the Psikharpax rat robot**", K Caluwaerts, M Staffa, S N'Guyen, C Grand, L Dollé, A Favre-Felix, B Girard, M Khamassi, ISIR UPMC.
22. "**Robot cognitive control with a neurophysiologically inspired reinforcement learning model**", M. Khamassi (ISIR Paris) S. Lallée, P. Enel, E. Procyk, P.F. Dominey (INSERM U846 Lyon).
23. "**Neural model of the subcortical saccadic selection in the tecto-basal loops**", Thurat C, N'Guyen S, Girard B, ISIR UPMC, LPPA Collège de France.
24. "**Revealing the time-course of biomechanics and visual information during motor decision-making**", Ignasi Cos, Paul Cisek, Department of physiology, University of Montréal
25. "**The Effect of Stimulus Novelty and Environmental-Volatility on The Neural Correlates of Adaptive Learning Rates**", Burak Erdeniz1,2 John Done2, 1University of Hertfordshire, School of Psychology, 2University of Hertfordshire, School of Computer Science, United Kingdom
26. "**Semi-Markov models of the molecular psychophysics of brain stimulation reward: a realtime model of decision-making with pure rewards and opportunity costs**", Ritwik K. Niyogi1, Yannick A. Breton2, Kent Conover2, Rebecca B. Solomon2, Peter Shizgal2 & Peter Dayan1, 1.Gatsby Computational Neuroscience Unit, UCL, London, UK, 2. Center for Studies in Behavioral Neurobiology, Concordia University, Montreal, Canada
27. "**tba**", Hadrien Orvoen, Sacha Bourgeois-Gironde
28. "**Reward risk coding in the orbitofrontal cortex: An intracranial electrophysiological study in humans**" Yansong Li[1,2], Giovanna Vanni-Mercier[1,2], François Mauguière[2,3] and Jean-Claude Dreher[1,2], *1 Center for Cognitive Neuroscience, Reward and Decision Making Group, CNRS, UMR 5229, 69675 Bron, France, 2 Université Lyon 1, 69003 Lyon, France, 3 Neurological Hospital, 69675 Bron Cedex, France*
29. "**Spontaneous fluctuations in brain activity account for preference instability**", Raphaëlle Abitbol, Maël Lebreton, Guillaume Hollard and Mathias Pessiglione, Motivation, Brain & Behavior (MBB) team, Institut du Cerveau et de la Moelle épinière (ICM), Groupe Hospitalier Pitié-Salpêtrière, Université Pierre et Marie Curie (UPMC – Paris 6)
30. "**May the force be with you: neural mechanisms underlying social drives of effort production**", Raphaël Le Bouc and Mathias Pessiglione, Motivation, Brain & Behavior (MBB) team, Institut du Cerveau et de la Moelle épinière (ICM), Hôpital de la Pitié-Salpêtrière, Université Pierre et Marie Curie (UPMC – Paris 6)
31. "**Dissociable costs: effects of expected versus experienced task difficulty on effort allocation**", Florent Meyniel, Lou Safra, Mathias Pessiglione, Motivation, Brain & Behavior (MBB) team, Institut du Cerveau et de la Moelle épinière (ICM), Hôpital de la Pitié-Salpêtrière, Université Pierre et Marie Curie (UPMC - Paris 6), France
32. "**Hemispheric dissociation of reward processing in humans: insights from deep brain stimulation**", Stefano Palminteri, Giulia Serra, Anne Buot, Liane Schmidt, Marie-Laure Welter &

Mathias Pessiglione, Motivation, Brain and Behaviour (MBB) team, Institut du Cerveau et de la Moelle Epinière (ICM), Hôpital de la Pitié-Salpêtrière, 75013, Paris, France

33. "**Physical effort diminishes neural sensitivity to outcomes in ventral striatum**", Irma Triasih Kurniawan[1], Marc Guitart-Masip[2], Peter Dayan[3], Raymond J. Dolan[2], 1 Institut du Cerveau et de la Moelle épinière, 2 University College London, Wellcome Trust Centre for Neuroimaging, 3 University College London, Gatsby Computational Neuroscience Unit
34. "**Spatiotemporal structure of Anterior Cingulate Cortex activity contributes to behavioral adaptation coding -A spike-train metrics analysis approach-**", Logiaco L. (1), Quilodran R. (2), Procyk E. (3) & Arleo A. (1), (1) Laboratory of Neurobiology of Adaptive Processes, UMR 7102, CNRS – UPMC Univ P6, Paris, France (2) Oficina de Educacion Médica, Facultad de Medicina Universidad de Valparaiso, Hontaneda 2653, Valparaiso, Chile (3) INSERM U846, Stem Cell and Brain Research Institute, Bron, France; University of Lyon, University of Lyon1, France

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POSTERS' ABSTRACTS

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(1) "**A self-organized neuronal comparator**"

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ABSTRACT

In order to develop a complex targeted behavior, an autonomous agent must be able to relate and compare the information received from the environment and generated internally by its different modalities [1] (e.g. deciding if the visual image currently being perceived is similar an image previously stored in the memory). For artificial agents, such basic comparison capabilities are typically either hard-coded or initially taught (e.g. by supervised learning), both processes involving the inclusion of predefined knowledge [2]. However, living organisms must acquire much of this capability only by interaction with the environment. We can therefore assume the presence of neural circuitry in living organisms, which is capable of comparing the information content received by different populations of neurons. Moreover, it cannot be assumed that these populations have a similar configuration, hold the information in the same encoding or even manage the same type of information (the case of different sensory modalities).

In the present work, we develop a "comparator" neural circuit which is capable of evolving from the correlations found in the information received. This circuit can autonomously acquire the capability of comparing the information received from different neural populations, which may differ in size and encoding used.

We used a two-layer feed-forward neural network, where the input layer receives two input signals. With a small probability, these inputs are related by a transformation, which represents the different encoding used for the same information. Using anti-Hebbian readjustment of the synaptic weights, the dynamics of the network minimizes its output without external supervision. This dynamics enabled the network to autonomously learn to differ via its output whether the two inputs are equal or not. This comparator can achieve an accuracy of up to _95%, despite the lack of any external information characterising the input.

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(2) "**Social feedback processing in East Asian and Western culture**"

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ABSTRACT

Background
Research in cultural psychology has established that people in East Asian cultures generally show more inter-dependent self-views whereas people in Western cultures show more independent selfviews (Markus & Kitayama, 1991). This culture-specific self-construal has been used to explain why East Asians rely more on external feedback in conformity studies (Bond & Smith, 1996). The current work tested whether East Asians incorporate self-relevant social feedback more into their views about themselves than Westerners. Interestingly, humans tend to show a positivity bias when receiving self-relevant social feedback, i.e. dismissing negative relative to positive feedback (Taylor & Brown, 1988). Therefore, we wanted to test whether both cultural groups show positively biased processing of social feedback. Medial prefrontal cortex (MPFC) activity is involved in making self- and other-judgments as well as in mentalizing tasks (Amodio & Frith, 2006). Interestingly, activity in more ventral parts of the MPFC has been shown to differ between East Asians and Westerners when making trait judgments about a close other (Han & Northoff, 2008). We therefore wanted to test whether social feedback activates MPFC or other regions involved in mentalizing and whether activity within these regions is modulated by culture.

Methods
Participants belonging to either Chinese (final n=27) or German (final n=27) culture got to know each other in groups of 5 by playing a board game. Afterwards each participant rated three out of the four other teammates on 80 trait adjectives. On the following day in the MR scanner, participants first rated themselves and then saw how the others had rated them. Importantly, the difference between own ratings and feedback could be desirable (i.e., feedback more positive than own rating) or undesirable (i.e., feedback more negative than own rating). To assess how participants updated their views, they rated themselves a second time outside the scanner. We obtained fMRI data from both cultural groups in Germany. To make sure that the behavior of the Chinese participants could not be attributed to living within a foreign culture, we additionally obtained behavioral data from Chinese (n=25) and Germans (n=24) living in China.

Results
Overall Chinese showed greater updating than Germans ($F(1,99)=8.9$; $p<0.005$). Participants also showed overall higher updating for desirable than for undesirable feedback ($F(1,99)=104.1$; $p<0.0001$). Importantly, greater updating of Chinese vs. Germans was not related to living in a foreign culture. Activity in the MPFC, left temporo-parietal junction (TPJ), right superior temporal sulcus (STS), and bilateral inferior frontal gyrus (IFG), was parametrically modulated by the absolute difference between own ratings and feedback ($p<0.05$, FWE corrected).

Conclusions
Members of an inter-dependent culture take feedback from peers more into account than members of an independent culture. Both groups show positively biased feedback processing. We report involvement of mentalizing-related regions in social feedback processing and we are currently testing how this activity differs across cultures.

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(3) "**Dynamics of Decision-Related Activity in Hippocampus**"

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ABSTRACT

Place-selective activity in hippocampal neurons can be modulated by the trajectory that will be taken in the immediate future ('prospective coding'), information that could be useful in neural processes elaborating choices in route planning. To determine if and how hippocampal prospective neurons participate in decision-making, we measured the time course of the evolution of prospective activity by recording place responses in rats performing a T-maze alternation task. After five or seven alternation trials the routine was unpredictably interrupted by a photodetector-triggered visual cue as the rat crossed the middle of central arm, signaling it to suddenly change its intended choice. Comparison of the delays between light cue presentation and the onset of prospective activity for neurons with firing fields at various locations after the trigger point revealed a 420 ms processing delay. This surprisingly long delay indicates that prospective activity in the hippocampus appears much too late to generate planning or decision signals. This provides yet another example of a prominent brain activity that is unlikely to play a functional role in the cognitive function that it appears to represent (planning future trajectories). Nonetheless the hippocampus may provide other contextual information to areas active at the earliest stages of selecting future paths, which would then return signals that help establish hippocampal prospective activity.

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(4) **"Modulatory Effect of Dopamine Receptors on Striatal Medium Spiny Neurons: A Computational Model"**

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ABSTRACT

The main input of basal ganglia, striatum which once considered to be involved in control of motor movement only, now is considered more for its role in reward related learning and decision making [1,2]. Though there are works related to the role of nucleus accumbens in reward-related learning and decision making, only recently the role of dorsal striatum in decision making has been examined [3,4]. Here, the effect of dopamine receptors on medium spiny neurons in direct and indirect pathways of dorsal striatum and its connected cortical network will be considered.

In order to investigate the modulatory effect of D1 and D2 receptors on the medium spiny neurons conductance based computational model will be given. The dynamic behavior of this model will be analyzed by bifurcation diagrams and it will be shown that different dynamical behavior can be obtained with parameter variation. These observed phenomenon will be explained in connection with the role of dopamine receptors on striatal medium spiny neurons.

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(5) "**To collect reward or to defend homeostasis? An integrated hypothalamo-basal ganglia circuit does both**"

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ABSTRACT

Reinforcement learning models address animal's behavioral adaptation to its changing "external" environment, and are based on the assumption that Pavlovian, habitual and goal-directed responses seek

to maximize reward acquisition. Negative-feedback models of homeostatic regulation, on the other hand, are concerned with behavioral adaptation in response to the "internal" state of the animal, and assume that animals' behavioral objective is to minimize deviations of some key physiological variables from their hypothetical setpoints. Building upon the drive-reduction theory of reward, we propose a new analytical framework that integrates learning and regulatory systems, such that the two seemingly unrelated objectives of reward maximization and physiological-stability prove to be identical. The proposed theory shows behavioral adaptation to both internal and external states in a disciplined way.
Neurobiologically, the cortico-basal ganglia circuit is long known to underlie reward learning and decision making. Midbrain dopamine neurons in this system, are hypothesized to carry the prediction error signal. Hypothalamic nuclei and their integration with the nucleus of the solitary tract (NTS), on the other hand, are widely studied for their role in homeostatic regulation. Recently, orexin-producing neurons are suggested to play as an interface between hypothalamus and the reward learning system, mediating interaction between the internal states and motivated behaviors. Exclusively synthesized in hypothalamus, orexin neurons are responsive to peripheral metabolic signals as well as deprivation level, and their direct projections to the ventral tegmental area (VTA) modulates the firing activity of dopamine neurons and feeding behavior. Using our theoretical framework, we attribute a central computational role to orexin neurons in generating the rewarding value of outcomes as a function of the animal's internal state.
Behaviorally, our proposed framework gives a normative explanation for anticipatory responses, as behavioral responses that occur in the absence of any physiological need, supposedly in order to prevent anticipated deviations from the homeostatic setpoint in the future. Furthermore, our framework allows for a unified explanation for some behavioral patterns including motivational sensitivity of different associative learning mechanism, interaction among competing motivational systems, and risk aversion. It also proposes several testable predictions.

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(6) **"The effect of novelty-based exploration on reinforcement learning mechanisms"**

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ABSTRACT
One of the basic adaptation mechanisms of living being is the exploration of novel, yet unknown environments. Exploration of a novel option may even be advantageous from an evolutionary point of view, since the new option may reveal to be more rewarding than the options exploited so far. It is thus not surprising that novel stimuli tend to be associated with a stronger explorative behavior in the context of a reward-based learning paradigm in humans. From a computational perspective it has been postulated that novel, unexpected stimuli are intrinsically rewarding, equivalent to a "novelty bonus".
The present study investigated the link between novelty-based explorative behavior and its influence on operand conditioning in a reward-motivated decision-making task. Subjects were familiarised with different categories and had subsequently to choose between two categories, one of which was more rewarding than the other. The goal of the task was to learn which of both categories was most rewarding. Depending on the condition, novel stimuli presented in one of the categories could have the effect of accelerating or decelerating learning, as compared to the control condition. The extent of this influence depended on the individual trait of novelty seeking. In order to investigate subject's behavior quantitatively, we developed different computational model-based and model-free reinforcement learning models. We introduced a bias parameter to allow for explorative behavior towards novel stimuli. Individual variation in novelty response was characterized by this bias parameter, which appeared to correlate with the individual novelty seeking trait and with the experimental novelty bias.
Additional fMRI analysis combined with the time series predicted by the reinforcement learning models further revealed a correlation between the prediction error signal and neural activations in the VS and VTA, which were stronger in novel rewarded trials as compared to standard rewarded trials. Also, the novelty-extended models explained more variance in the fMRI data as compared to the standard version

without novelty parameter. The fMRI results are in line with previous studies and confirm that novelty and reward seem to be encoded by a similar neural signal.
Altogether, we have not only shown that novel stimuli have a direct influence on learning processes depending on reward probabilities, but also that novelty enhances neural responses underlying reward anticipation in decision-making. These results as well as individual differences could be reproduced by our computational models.

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(7) **"Computational Study of Neuronal Mechanisms Underlying Value-Based Decision Making"**

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ABSTRACT

Value-based decision making is a cognitive process in which an animal selects a specific behavior from a set of alternatives. The selection is based on the anticipated reward associated with each behavioral alternative (i.e., subjective values). Subjective values are established, in part, by reinforcement learning (RL). Substantial progress is being made in identifying neural systems, microcircuits and cellular mechanisms of decision making. However, dynamical and structural complexity make it difficult to achieve a comprehensive understanding of mechanisms that underlie value-based decision making. Computational models can help address this issue. Computational models provide a quantitative framework for simultaneously studying multiple levels of organization, testing the validity of assumptions, and assessing the roles of component processes. Moreover, modeling studies can help identify general principles that apply to a variety of animal species and to diverse behavioral circumstances, and that can be adapted to artificial systems.

We are using modeling studies to investigate the ways in which an identified neural circuit in *Aplysia* selects between two alternative feeding behaviors: ingestion vs. rejection [4]. The neurosimulator SNNAP [2] was used to develop a neurobiologically plausible model network with cells B4, B8, B31, B34, B35, B51, B52, and B64 [3]. These cells are elements in a central pattern generator (CPG) that mediates feeding. The model simulated features of fictive feeding. Currently, the model is being extended by: 1) including an autapse in B31; 2) adding CPG cells B20, B30, B65, B65 and CBIs 2-4; and 3) incorporating identified correlates of operant conditioning. Simulations indicated: 1) the autapse and positive feedback among B31, B34, B35, B63 and B65 mediated the decision to initiate fictive feeding; 2) incorporating the known neuronal correlates of operant conditioning [1,5] (*i*) reduced the threshold for eliciting fictive feeding, (*ii*) biased the neural activity toward fictive ingestion; the bias toward ingestion resulted from changes in B51, whereas the reduced threshold resulted from changes in cells B63 and B65 and the electrical coupling among cells B30, B63, and B65. Finally, the results suggested that as yet unidentified modifications are necessary to produce more complete ingestion-like neural activity.

Our computational studies suggested that value-based decision making involve multiple sites of plasticity. These sites mediate the initial commitment to respond and assignment of subjective values. The interplay among these sites biased the fictive feeding behavior toward a single, highly valued response, which previously had been associated with positive reinforcement. Finally, these studies are providing an opportunity to simultaneously investigate decision making at theoretical, algorithmic, and implementation levels and are providing insights into cognitive processes.

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(8) **"Diffusion-weighted imaging tractography-based parcellation of the human dorsal prefrontal cortex and comparison with human and macaque resting state functional connectivity"**

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ABSTRACT

The importance of the prefrontal cortex in decision-making process is beyond doubt, but a more fine-grained understanding of the role of the different prefrontal areas is still a major goal of cognitive neuroscience. Surprisingly we do not know much about the structural connectivity of the different areas of the human prefrontal cortex, even though a brain region's connections to the rest of the brain strongly constrain its functions. Our knowledge of human brain organization is principally based on its cytoarchitecture and on inferences from neuro-anatomical studies in non-human primates and rodents. Recent developments in Diffusion Tensor Imaging (DTI) now enable the study of the structural connectivity of the human brain. In this experiment, DTI was used to investigate connectivity profiles of dorsal prefrontal cortex. First, an algorithm was used to search for regional variations in the probabilistic connectivity profiles of all prefrontal cortex voxels with the whole of the rest of the brain. The results of this analysis were submitted to a clustering algorithm to determine clusters that slow similar connectivity profiles. Second, the probabilities of connection between identified clusters and predefined target regions of interest were calculated, so as to determine a connectivity fingerprint for each region. We then explored the potential of resting-state functional connectivity to describe interactions between each of the clusters found in the data tractography-based parcellation of the human dorsal prefrontal cortex.

A consistent clustering across subjects that followed known cytoarchitectonic differences was found. In the dorsal prefrontal cortex, they suggest a dorso-ventral and rostro-caudal segregations of clusters. Patterns of functional connectivity resembled those that might have been expected from tract tracing studies in macaques. Finally a similar approach was used in macaques enabling us to make direct comparisons between human and macaque DTI data and between macaque and DTI and tracer injection studies.

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(9) **"Quantitative modeling of the biological substrates of the Basal Ganglia : suitable for what kind of selection ?"**

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ABSTRACT

Computational modeling in neuroscience is the art of programming a mathematical model built upon our biological knowledge of the brain, in order to gain more knowledge on it. Yet, quantitative biological knowledge is hard to integrate with the traditional method of fine-tuning by the modeler, because: (1) most of the time, the quantitative data needed to build the model are not known; (2) when they are known, it is up to a given confidence range; (3) in some other cases, data have become almost too abundant to be handled "by hand", and on top of that a non-negligible part of these seem to be contradictory (e.g. the firing rates at rest of the various nuclei).

Our work addresses the issue of plausibility in the crafting of computational models of the Basal Ganglia, and proposes a novel method which respects to the best extent a wide collection of biological data. We achieve to find parameterizations that constitute different trades-off between reproducing best quantified

data from several dozens of anatomical studies and reproducing best a dozen of measurements from electrophysiological studies, resulting in highly plausible computational models of the Basal Ganglia. According to the mainstream theory, the Basal Ganglia operate a selection among cortical input signals. While these models have been have been optimized to fit well with biological data, there has been no pressure toward selection during the models optimization. By studying how selection is then processed by these models, we are able to make predictions on the ways the Basal Ganglia does process its inputs to select among different options. In this study, we also challenge the view that the anatomical structure of the Basal Ganglia is perfectly designed to operate selection, as we show that some parts of this structure hinder the selection capability.

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(10) "**Contribution of the Ventral Striatal Pathway to Decision Making**"

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ABSTRACT

The role of dorsal striatum in goal-directed behaviors and decision making has been studied widely. In the last decade, there have been complimentary works proposing that the ventral striatum, namely nucleus accumbens, influences the dorsal striatum through midbrain dopamine cells [1]. Nucleus accumbens, especially shell region, has an important function in determining the reward value of tasks in goal-directed behavior and the error in expectation [1]. Various works demonstrate the effects of nucleus accumbens in delayed reinforcement on action-outcome learning [2]. Nucleus accumbens related dopamine transmission is involved in effort-related decision making processes [3]. It is suggested that through the striato-nigro-striatal pathway, limbic regions have impact on the motor regions of the basal ganglia and also ventral pallidum acts as an integrator between nucleus accumbens and other parts of the brain [1,3].

The computational model we proposed focuses on the modulatory effects of nucleus accumbens related dopamine secretion in the dorsal striatal decision making process. Thus a conductance based computational model is introduced to reveal the contribution of ventral striatal pathway.

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(11) "**From tug of war to horse racing: Deep brain stimulation reduces the influence of decision conflict in perceptual decision making.**"

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Keywords: *DBS, STN, Perceptual Decision Making, Optimal decision making, Algorithmic models*

ABSTRACT

Neurocomputational models of the basal ganglia (Gurney et al., 2001; Bogacz, 2007; Bogacz and Gurney, 2007) have proposed that the subthalamic nucleus (STN) plays a crucial role during decision making. The STN sends a breaking signal to the output structures of the basal ganglia effectively slowing down decision making when decision conflict exits (Frank, 2006). This has an effect on sensorimotor

transformations in PD patients, as deep brain stimulation (DBS) of the STN impairs this conflict computation leading to more impulsive decision making during high conflict choices (Frank et al., 2007; Zaghloul et al., 2012). Specifically, these models predict that DBS, which may disrupt information processing in the STN, should diminish the influence of decision difficulty on reaction time (RT).
To test these predictions we asked PD patients to judge the direction of prevalent motion in random dot stimuli under different DBS states. Trials differed in difficulty (motion coherence) and instruction to respond fast or accurately. Behavioral results indicate that DBS significantly influences performance for difficult perceptual judgments as well as the magnitude of adjustment between response instructions. In particular, when DBS was turned off, RTs increase substantially as the task becomes more difficult. By contrast, when DBS was turned on, the influence of decision difficulty on RT was significantly lower. Importantly, these findings are consistent with computational models and experimental evidence, which suggest that the STN is crucial for adjusting decision making on difficult, high conflict trials (Frank et al., 2007; Cavanagh et al., 2011; Zaghloul et al., 2012). Model fits demonstrate that DBS reduces the magnitude of adjustment of the decision criterion and support the algorithmic framework of corticobasal ganglia computation for optimal decision making (Bogacz and Gurney, 2007).

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(12) **"Pain Enhances Reward Seeking Behaviour and Reduces Fairness during a Bilateral Ultimatum Game"**

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ABSTRACT

Social preferences like interpersonal altruism, fairness, reciprocity and inequity aversion are inherently linked to departures from pure self-interest. During economic interactions, for example, defectors may be punished even if this implies a cost for the punishers. This violation of canonical assumptions in economics indicates that socially oriented decisions may predominate over self-centred stances. Here we

explore whether the personal experience of pain changes the balance between self-gain and socially based choices.

We used laser stimulation to induce pain or a warm sensation in 24 participants playing a modified version of the Ultimatum Game (UG) both in the role of responder and proposer. When acting as responders participants received the offer contemporaneously to a painful or warm laser stimulation. They could accept or reject the offer by means of a button press. Subsequently, a feedback informed participants how much they received and they could rate the fairness of the offer on a VAS scale. When acting as proposers participants had to decide how to split money (1€), selecting the corresponding offer by clicking with the cursor on the image displayed on the screen. The painful or warm laser stimulation was delivered previously to offer presentation. No feedback was provided in order to avoid that the responders' choice influences the subsequent offer. Moreover, responders and proposers rated the intensity and unpleasantness of the sensation evoked by the laser stimulation.

Results show that suffering responders increase their acceptance rate irrespective of economic offer and suffering proposers decrease fair offers. Crucially, the intensity of painful stimulation has a predictive role on Moderately Unfair offers' acceptance rates. Thus the personal experience of pain may favour the emergence of a self-centered perspective aimed at maximizing self-gain. The results raise the possibility that perceiving pain might influence economic interactions, reversing the original preference for fairness and inducing a reward seeking behavior.

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(13) **"The neurophysiology of deceptive decision making in social interactions"**

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ABSTRACT

If we picture ourselves lying we certainly imagine this act as more demanding that truth-telling. Studies supporting the notion that lying is cognitively more demanding than telling the truth (cognitive load hypothesis of deception) used experimental paradigms which ignored the fundamental issue of the moral conflict related to deception.

He we used a novel, ecological experimental paradigm and we measured both the cognitive cost (by means of reaction times and stimulus-locked event related components) and the moral cost (by means of the readiness potential and its correlations with deception-related personality traits).

EEG signal was recorded from sixteen subjects (SP) while they were playing an on-line card game with an opponent player (OP). The OP had to choose one of two covered decks, one associated with gain and the other with loss, unaware of the outcome of his own choice. SP could saw the outcome and were supposed to report it to OP. By lying, SP could have the chance to reverse the outcome in order to win when he/she had actually lost (self-gain lie) or to lose when he/she had actually won (altruistic lie). SPs performed the game in two conditions: the Reputation-Risk (R), in which OP was informed about SP behaviour; and the No-Reputation Risk (NR) in which the OP was not informed.

Results show that when people are free to decide whether to deceive or not another person, lying does not require any additional cognitive workload as indexed by absence of difference in reaction times or in the stimulus-locked components known to be influenced by attention to stimuli (N1), task-relevant stimuli perception (P2) or task cognitive workload (P3). Importantly, lying was associated to a reduced motor readiness in the presence of specific deception-related personality traits. In particular, the more people were manipulative the less they showed a lie-related reduction of motor readiness; the more they cared about their impression management the more they showed a lie-related reduction of motor readiness. These results point out the importance of moral cognition in deceptive decision making.

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(14) **"How Cholinergic Innervation in Hippocampus Contributes to Early Memory Development and Attention ?"**,

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ABSTRACT
Although ACh is generally known to regulate the structural maturation of the central nervous system – e.g., the growth, differentiation, and plasticity of the neurons– the precise timing of cholinergic innervation to the cortex appears to be crucial for the normal development of cognitive functions. Its action is even broader since ACh has been identified for mediating the propagation of slow waves of electrical activity in the developing neocortex, which are associated with long-term memory and categorization performances. Hence, the modeling of the cholinergic system in the para-hippocampal system is not only critical for understanding development during the first year but also for understanding memory transfer, attention processes and retrieval task.
In our research, we propose to model the cholinergic system innervation in the hippocampal systemi and its influence to learning, attention and memory development. During the peri-natal period, the neuromodulator acetylcholine (ACh) is involved in the structural and functional adjustments of the hippocampus, transforming it into an attentional system; i.e., a working memory for novel information. Under its action, the entorhinal cortex sustains and facilitates the learning of novel stimuli relative to the old patterns already present in the hippocampus. We show in our experiments how this dual mechanism can generate simply some emergent properties necessary for cognitive development. For instance, it limits the interference between memories which has for effect to scaffold the memory organization and to discretize the memory space into separated categories at the same time. Moreover, we show how theta waves slowly shape the neocortical maps into coherent patterns (rhythmical theta/gamma activity). Our cholinergic hypothesis may give some partial answers to the paradoxes that pose the hippocampus and other subcortical structures that appear to function at birth but show some evidence of slow development and/or functional reorganization. Here, we propose that the neurotransmitter acetylcholine may play the role of a "catalyst" that activates the functional organization of the cortico-hippocampal system (i.e., detecting and holding stimuli, preserving and acquiring memories).

Pitti A. & Kuniyoshi Y. (2011) Modeling the Cholinergic Innervation in the Infant Cortico-Hippocampal System and its Contribution to Early Memory Development and Attention. *Proc. Of the International Joint Conference on Neural Networks IJCNN 2011*, pp.1409-1416.

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(15) "**Encoding and Planning Sequences of Arm Gestures with a Bio-inspired Model of Cognitive Maps**"

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ABSTRACT
Robots should be able to learn what they are expected to do. Programming by demonstration [1] focuses on learning from interaction with others. In this paper we study how the principles of a bio-inspired model of cognitive map developed for navigation [2] can be adapted to arm control and on-line learning of manipulation tasks from interaction.

In [2], the cognitive maps were used to tackle navigation tasks. Visual "what" and "where" and where information are merged to build place-cells at the level of the Enthorhinal Cortex (EC). The Hippocampus (Hs) receives their activities. Hs detects changes of winning place-cell that are then encoded as transitions. The maintained place-cell activity in the Dendate Gyrus (DG) activates in CA3 the next possible transitions. A topological map (cognitive map) of the sequences of the transition is encoded as recurrent connections in the frontal cortex and the parietal cortex. At the reception of a reward corresponding to a specific drive (e.g. water to relieve thirst), an association between the motivation (thirst) can be made with the rewarded goal transition. The recurrent connections enable to propagate the activity from the rewarded transition to the different transitions depending on their positions in the topological map. The propagated activities can come to bias the selection of the transition to be done. The system perform the action that correspond to following the transitions leading to the closest most

rewarded goal transition. Using proprioceptive state categories as input, this whole model can be easily adapted to control a multi-DOF robotic arm.
The cognitive map based architecture was implemented on a robot composed of a robotic arm and a camera [3]. The gestures to be done were demonstrated by a passive manipulation of the robotic arm. As the robotic arm moves, the proprioceptive configuration of the robot changes i.e. the joint positions and the activation of the close range sensors (IR, force) on the gripper. With the resulting cognitive map, when the camera focuses on a take-can spot in order to recognize the motivational context (simple color detection), the chosen transitions activate a motor configuration that commands a lower level motor control. The model was applied to a task where the robot learns to sort different cans and to put them at different places.
In this work we described a model for encoding and planning sequences of arm gestures. This model is adapted from a cognitive map based architecture used in navigation task. By gathering in the same whole architecture the control for navigation and manipulation we aim at simplifying the control on task that would merge both. Current ongoing work focuses on implementing such an architecture on a mobile robot carrying a robotic arm.

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(16) "**Multimodal integration of visual place cells and grid cells for robots navigation**"
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ABSTRACT
In the present study, we propose a model of multimodal place cells merging visual and proprioceptive primitives. We will introduce a new model of proprioceptive localization, giving rise to the so-called grid cells [Hafting2005], wich are congruent with neurobiological studies made on rodent. Then we briefly show how a simple conditionning rule between both modalities can outperform visual-only driven models.

In previous works, we developped a model of the hippocampus to obtain visual place cells [O'Keefe&Nadel 78] that allowed controlling mobile robots for visual navigation tasks [Gaussier&al 2002]. A Place Cell (PC) learns to recognize a specific landmarks-azimuths constellation from a visual panorama. A neural network learns to associate a PC with an action (a direction to follow). These kind of architecture linking sensation and action is named Per-Ac [Gaussier95] and allows the robot to learn robust behaviors. Since it has been successfully tested in simple environments, it shows limitations when trying to scale to larger and more complex ones (multi-room, outdoors). Visual ambiguities are the major problem. We propose to add a model of grid cells based on various modulo's operator applied on extra hippocampal path integration [Gaussier2007]. In this model, randomly chosen neurons of the path integration field are discretized, then projected on smaller fields (modulo projections). The conjunction of two of these fields is sufficient to obtain grid cells. A recalibration mechanism associate the current path integration activity with a particular PC, allowing the system to recalibrate itself when this PC is later well-recognized. It reduces cumulated errors of odometry.
We obtained coherent grid-like activities of different phases, orientations and spatial frequencies. To overcome limitations of visual-only based models we propose a simple merging system which can take

profit of allothetic and idiothetic information. This mechanism is based on a simple pavlovian conditioning rule between visual PCs (unconditional stimuli) and grid cells (conditional stimuli). Results obtained during a multi-room indoors experiment (in our laboratory) show well-defined place field even if errors happen on both modalities. This model pops up the synergy of correlated activities, reducing singular ones.
Our experiments emphasized some issues while trying to scale visual-only architectures to large environments: visual ambiguities have been identified as the major problem. Consequently, we extended it by modelling grid cells and we presented a robotic experiment that can account for their firing properties. Then, we show how a simple merging mechanism exploiting these grid cells can disambiguate vision and generate robust multimodal place cells. It successfully overcome the perception ambiguity problem and stay robust even if errors simultaneously happen on both modalities. Our current work focuses on switching navigation strategies according to an emotional metacontroller based on bayesian inferences. In the same time, we are performing long range (several kilometers) outdoor navigation experiments based on these models.

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(17) "**Synchrony as a Tool to Establish Focus of Attention for Autonomous Robots**"
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ABSTRACT
Synchrony is a crucial parameter for non-verbal social interaction as well as largely witnessed in natural dynamical systems. Psychological Studies of dyadic interactions shows that synchrony is a necessary condition for interaction between an infant and his mother [1]. Recently, Dumas et al.[2] revealed, using hyperscanning, the emergence of inter-brain synchronization across multiple frequency bands during social interaction. Interpersonal motor coordination between people can also be observed while walking along someone [3]. In this paper, we use immediate synchronous imitation as a communication tool. Inspired by development in psychology, neurobiology and physics, we present here a neural network architecture for socially interacting robots.
We used a minimal setup for our experiments. Components includes Nao robot, basic automata (1 degree of freedom), human and cameras. To analyze synchrony, we need to investigate the dynamics of interaction between two signals. To do so, we use the Phase Locking Value (PLV) [4]. Videos of our experiments can be found on: http://www.etis.ensea.fr/neurocyber/Videos/synchro/. Here, we propose a model based on dynamical interactions of two agents. Agent 1 (Nao robot) dynamically adopts or imitates the behavior of agent 2 (human / automata). Our aim is to provide to Nao limited capabilities to interact with other agents by dynamically adopting the frequency and phase of the other agents. Nao's motor oscillator model is made of two neurons N1 and N2, fed by a constant signal and multiplied by the parameters alpha1 and alpha2 (equation 1). These two neurons inhibit each other proportionality to the parameter beta.
Motion in the visual field of Nao is estimated by an optical flow algorithm, velocity vectors are then converted into positive and negative activities (upward and downward movements). When an agent interacts with a motion frequency close to NAO's frequency, Nao's oscillator can be modified within certain limits otherwise it continues to his default frequency.
By linking the Nao's oscillator which controls the arm movement to an oscillator-prediction module instead of using the induced energy, we obtain a neural network architecture that selects an interacting partner on the basis of synchrony detection by entertaining the visual stimuli (optical flow) that is similar to its own motion (learnt by the oscillator-prediction module).
To show that the human attentional mechanism (based on synchrony) can be applied to robots also, we use prediction of synchrony as a parameter to attract the attention of the robot. If two visual stimuli are presented at the same time and only one of them has the same frequency as NAO. NAO will then synchronize with the "interacting" partner corresponding to his frequency and select him as a partner. However, NAO will not be able to locate the good interacting partner in its visual field, because this algorithm (partner selection) works on the perceived energy irrespective of the spatial information (agent location). To locate the correct interacting partner, the proposed FOA (Focus Of Attention) algorithm dynamically locate the correct interacting partner using spatial predictions.

Mainly influenced by neurobiology and psychology of unconscious communications between humans, we proposed a novel approach for building autonomous robots that can interact with multiple agents and select an interacting partner among several on the basis of synchrony detection. We also showed that synchrony prediction could be used as a way to establish focus of attention.

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(18) **"Neural coding in the cortico-striatal system in a decision making task: Insights from reservoir computing"**

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ABSTRACT

The cortico-striatal system, a striking component of primate neuroanatomy, plays a major role in decision making and sequence processing. Quilodran et al. developed a decision making task (Quilodran et al. 2008) with a clear separation between an exploration phase where monkeys explored targets to find that which was rewarded by fruit juice, and a exploitation phase where monkeys could repeat the rewarded choice. Activity in the anterior cingulate cortex (ACC) and lateral prefontal cortex (LPFC) was recorded. A significant number of neurons showed a clear dynamical shift between the search and repeat phase. Certain neurons specifically encoded the first reward, which crucially indicated the shift from exploration to exploitation. However, equally important, the last chosen target was not explicitly represented in neuronal activity at the time of target choice.

We simulated the cortico-striatal system in the framework of reservoir computing (Jaeger et al., 2001). The reservoir, a recurrent network of leaky integrator neurons with nonmodifiable connections develops a non-linear activity over time that reflects the history of its inputs. A readout layer fully connected to the reservoir uses this activity to produce the desired output associated with the input sequence by linear regression learning. We considered that the reservoir models the cortex and the readout represents the striatum. Our objective was to assess the ability of the model to reproduce the behavior and the cortico-striatal dynamics observed in the electrophysiological results exposed above.

The reservoir was trained with random vs. ordered strategies for exploration of the targets. Random search elicited poor performance while ordered exploration was almost perfect. Secondly, we trained the reservoir with the behavior from a monkey efficiently performing the task. The results, while slightly inferior to those for ordered search showed that the monkey had a rather structured behavior since the reservoir was able to learn the task from that behavior. Reservoir activity displayed similarities with unit recordings from monkeys, and also explained certain paradoxical observations. We found neurons showing a shift in activity between the exploration and exploitation as seen in biological neurons. While no reservoir neuron responded only to the first reward, neurons could be successfully trained to respond to it, demonstrating that the crucial information to shift from exploration to exploitation was present in the reservoir even if it was not explicitly expressed by single neurons. Similarly, while as in the monkey, no single units encoded the previously chosen target (crucial for deciding the next choice), trained neurons demonstrated that this information was robustly present in the reservoir, an important results emphasizing that unexpressed information may be sparsely encoded in the activity of neural populations.

Reservoir computing can be considered as an interesting tool for the study of higher cognitive function, including characterization of primate behavior and neural activity. Indeed, our model provides a novel response to an open question concerning the coding of previous behavior in planning for the future.

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(19) **"Computational modeling of reinforcement learning in alcohol use disorder"**
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ABSTRACT
In cognitive neuroscience, reinforcement learning (RL) is investigated mainly in two streams: habitual and goal-directed. Habitual learning is based on the temporal-difference (TD) learning related to dopaminergic system which has a "model-free representation" in the sense of working without the representation of task structure. Goal-directed system, by contrast, is "model-based" which has some way of representing the "internal model" of the task. It has been proposed that higher cognitive regions govern this type of learning such as the prefrontal cortex which has long been associated with higher-order cognitive functions, including working memory, planning, and decision making. The interaction of these two types of learning is still obscure and especially in the case of addiction, which is defined as the compulsive use of the addictive substance, a transition between these two learning types is observed. Addiction usually starts with the model-based learning in which an addict is well aware of the high-order structures of his/her behavior such as the interdependencies between the stimuli-action pairs and the following rewards but then that type of learning gradually leads to the model-free habituation in which the person finds him/herself doing this compulsive behaviour reporting an "out of control" feeling. We will show how these "model-free" and "model-based" approaches are used to find the distinct model parameters which are presumed to show individualistic characteristics of the subject behavior. The paradigm we choose for this purpose is a two choices probabilistic reversal task where subjects have to learn which of the two choices is more rewarding, and then flexibly switch their choices when contingencies change. The behavioral data of 59 age and sex matched subjects (26 healthy control subjects and 33 alcohol-dependent subjects) are first analyzed using the temporal-difference theory (TD learning) which is based on the calculation of prediction errors for each trial and the estimation of choice values and action probabilities. There will be 14 versions of this model class, each formulating the problem differently and using different sets of free parameters consisting of learning rate, decay rate, reward coefficient, punishment coefficient, initial value and exploration-exploitation trade-off parameter. For the model-based class, a Hidden Markov Model (HMM) is utilized where a transition matrix and an observation matrix are estimated for each subject which are assumed to be used during the whole course of the task. Finally, the two model classes will be compared with respect to the behavioral differences between the two groups. For the model comparison, in addition to Bayesian information criterion (BIC), which is a commonly used in behavioral neuroscience as a model comparison and selection tool, we will also apply a relatively less utilized model comparison methodology in our field of study– cross validation. We will show that model-based class performs better than the model-free one in terms of less overfitting and better representation of the behavior. On the other hand, although there is no significantly different behavioral representation between the groups, this is a very promising finding for the upcoming model-based fMRI study which we will regress the state prediction error derived from the model-based approach in which we expect to see functional activity differences among our experimental groups.

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(20) "**Which Temporal Difference Learning algorithm best reproduces dopamine activity in a multi-choice task ?**"

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ABSTRACT

The activity of dopaminergic (DA) neurons has been hypothesized to encode a reward prediction error (RPE) which corresponds to the error signal in Temporal Difference (TD) learning algorithms. This hypothesis has been reinforced by numerous studies showing the relevance of TD learning algorithms to describe the role of basal ganglia in classical conditioning. However, recent recordings of DA neurons during multi-choice tasks raised contradictory interpretations on whether DA's RPE signal is action dependent or not (Morris et al., 2006; Roesch et al., 2007). In Morris et al. (2006), the RPE signal carried by recorded DA neurons appeared to depend on the action the animal would subsequently perform and to be consistent with the SARSA algorithm. In Roesch et al. (2007), DA neurons appeared to encode an error depending on the value of current best option, thus consistent with Q-learning. Thus the precise TD algorithm (i.e. Actor-Critic, Q-learning or SARSA) that best describes DA signals remains unknown.

Here we simulated and precisely analyze these TD algorithms on a multi-choice task performed by rats (Roesch et al., 2007). We found that none of these algorithms could satisfyingly reproduce the observed patterns of responses when keeping the behavioral parameters. However, when the learning rate of behavioral adaptation and the learning rate of the adaptation of the expected value were dissociated, we found that Q-learning and Actor-Critic could both reproduce DA activity during the delay condition while Sarsa could not.

First, this suggests that instead of only reporting the averaged post learning DA activity, showing the trial-by-trial evolution of DA's response accross learning may be more informative, and may lead to different conclusions on which algorithm among Actor-Critic, Q-learning and SARSA best describes the activity. Second, this suggests that the observed behavior is not the direct consequence of a unique learning system that we suppose relies on the recorded DA activity. This could indicate the presence of a second parallel decision system which speeds up the behavioral adaptation, for instance a cortically driven goal-directed system (Daw et al., 2005).

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(21) "**A biologically inspired meta-control navigation system for the Psikharpax rat robot**"

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ABSTRACT

A biologically inspired navigation system for the mobile rat-like robot named Psikharpax is presented, allowing for self-localization and autonomous navigation in an initially unknown environment. The ability of parts of the model (e.g. the strategy selection mechanism) to reproduce rat behavioral data in various maze tasks has been validated before in simulation. But the capacity of the model to work on a real robot platform had not been tested. This paper presents our work on the implementation on the Psikharpax robot of two independent navigation strategies (a place-based *planning* strategy and a cue-guided *taxon* strategy) and a strategy selection meta-controller. We show how our robot can memorize which was the optimal strategy in each situation, by means of a reinforcement learning algorithm. Moreover, a context detector enables the controller to quickly adapt to changes in the environment—recognized as new contexts—and to restore previously acquired strategy preferences when a previously experienced context is recognized. This produces adaptivity closer to rat behavioral performances and constitutes a computational proposition of the role of the rat prefrontal cortex in strategy shifting. Moreover, such brain-inspired meta-controller may provide an advancement for learning architectures in robotics.

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(22) "**Robot cognitive control with a neurophysiologically inspired reinforcement learning model**"

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ABSTRACT
A major challenge in modern robotics is to liberate robots from controlled industrial settings, and allow them to interact with humans and changing environments in the real world. The current research attempts to determine if a neurophysiologically motivated model of cortical function in the primate can help to address this challenge. Primates are endowed with cognitive systems that allow them to maximize the feedback from their environment by learning the values of actions in diverse situations and by adjusting their behavioral parameters (i.e. cognitive control) to accommodate unexpected events. In such contexts uncertainty can arise from at least two distinct sources - expected uncertainty resulting from noise during sensory-motor interaction in a known context, and unexpected uncertainty resulting from the changing probabilistic structure of the environment. However, it is not clear how neurophysiological mechanisms of reinforcement learning and cognitive control integrate in the brain to produce efficient behavior. Based on primate neuroanatomy and neurophysiology, we propose a novel computational model for the interaction between lateral prefrontal and anterior cingulate cortex (LPFC and ACC) reconciling previous models dedicated to these two functions. We deployed the model in two robots and demonstrate that, based on adaptive regulation of a meta-parameter β that controls the exploration rate, the model can robustly deal with the two kinds of uncertainties in the real world. In addition the model could reproduce monkey behavioral performance and neurophysiological data in two problem-solving tasks. A last experiment extends this to human-robot interaction with the iCub humanoid, and novel sources of uncertainty corresponding to "cheating" by the human. The combined results provide concrete evidence for the ability of neurophysiologically inspired cognitive systems to control advanced robots in the real world.

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(23) "**Neural model of the subcortical saccadic selection in the tecto-basal loops**"

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ABSTRACT
The Superior Colliculus (SC) is a well-known generator of saccadic movements. Its reciprocal connectivity with the Basal Ganglia (BG) has recently been emphasized (McHaffie et al., 2005, TRENDS in Neurosciences, 28(8), 401-407), as well as its implication in selection processes (McPeek and Keller, 2004, Nature Neuroscience, 7(7), 757-763, among many other papers published since 2000). Regardless of the role of the BG in selection, numerous experimentalists suggested that selection in the SC results of lateral inhibitions. (Arai & Keller, 2004, Biological Cybernetics, 92, 21-37) have hypothesized in their computational model that the BG could play an important role in the selection of targets in a purely subcortical SC-BG circuit, but did not propose a full functional model of this circuit, the BG having the role of external inputs. We investigate the possibility that selection in the SC results from SC-BG interaction, using a model linking together recent SC (Tabareau et al, 2007, Biological Cybernetics, 97, 279-292) and BG (Girard et al., 2008, Neural Networks, 21, 628-641) models. We managed to reproduce experimental data gathered by (McPeek and Keller, 2004) regarding deficits in target selection after inactivation of the SC. Within these constraints, our first results show that the presence of a biomimetic race model is needed in the superficial layers of the SC, as well as several inhibitory feedback projections from the BG to the SC, in order to allow clear selection in case of identically salient targets. Furthermore, the activity profile of the neurons in this new layer seem to be akin to that of prelude Visuo-Motor (VM) neurons found in the SC, which points to proving the soundness of the model, as well as giving a hypothesis for the role of these prelude VM neurons.

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(24) **"Revealing the time-course of biomechanics and visual information during motor decision-making"**

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ABSTRACT
There is considerable debate about the influence of the arm's biomechanical properties on the planning of voluntary movements. While several models describe reach planning as primarily kinematic, some studies have suggested that implicit knowledge about biomechanics may also exert influence on the planning and preparation of reaching movements. We addressed this matter in a preliminary experiment, in which human subjects made free choices between two potential reaching movements, varying in path distance and biomechanical factors related to movement energy and stability. Our results show that subjects preferred movements whose final path was best aligned with the direction of lowest biomechanical cost, even when the launching properties were very similar, therefore suggesting that the nervous system can predict biomechanical properties of potential action prior to movement onset, and that these predictions, in addition to purely abstract criteria, exert an influence on decision-making.
Here we examined the latencies at which different factors influence motor decision-making prior to movement onset. Hypothetically, if the encoding of factors, such as distance or direction is attributed to the fronto-parietal loop and the computation of biomechanics to the cerebellum, their latencies to reach the motor plan should be significantly different. To test this, we constrained the subjects' observation time of the geometrical arrangement prior to movement onset to a range that varied between 200 and 1000ms. Unexpectedly, the subjects' choices showed that the biomechanical factor precedes the influence of target distance, therefore suggesting that the calculation of biomechanical factors may take advantage of priors including knowledge of biomechanics along different arrival directions.
In summary, these results provide an insight into decision-making of reaching movements, demonstrating not only that biomechanics and stability are two influential factors, even prior to movement onset, but also that motor decision-making is a gradual process, first incorporating intrinsic and stability properties to the motor apparatus and secondly visual factors, potentially seeking to maximise comfort.

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(25) "**The Effect of Stimulus Novelty and Environmental-Volatility on The Neural Correlates of Adaptive Learning Rates**"

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ABSTRACT
Several mathematical accounts of conditioning suggests that learning rates should change overtime as the animals' get familiar with the conditional stimulus (CS) (Machintosh, 1975; Pearce & Hall, 1980). In the learning literature researchers used various adaptive learning rate models where the common point between these models is that over successive trials the learning rate decreases (Schumajuk, 1997). Numerous Function brain imaging studies utilized computational reinforcement learning models with fixed learning rates in their model fitting procedures. Fixed learning rate models have been successfully used to find neural correlates of certain hidden variables like the prediction error responses and have various advantages when comparing the differences for example the learning deficits of a particular group or subpopulation. However, fixed learning rates doesn't capture certain behavioral and physiogical findings (i.e., the predicted value of the conditional stimuli don't get affect by the prediction error signals in the late trials as much as early trials) and several researchers utilized adaptive learning rate models in their imaging studies (Behrens et al., 2007; Haruno & Kawato, 2006).

In this study we used a simple probabilistic reinforcement-learning task with novel and familiar stimuli. Eighteen Participants were pre-trained outside the scanner with the familiar stimuli and the associated outcomes for each condition was learned prior to the scanning session. For both familiar and novel stimuli, we used three different probabilistic outcome contingencies in order to test the effect of environmental volatility on the neural correlates adaptive learning rates. By performing a model-based analysis, we showed that novel stimuli increase the value of the learning rate parameter as well as environmental-volatility. The imaging results also showed that adaptive learning rates enhance the

activation in ventral striatum and cingulate cortex where as both familiar and novel learning rate activation was found on the motor cortex. We argue that this effect may enhance behavioral learning via changing the sensori-motor cortico-striatal plasticity, which may be linked to the learning rate parameter that determines the impact of the prediction error.

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(26) "**Semi-Markov models of the molecular psychophysics of brain stimulation reward: a realtime model of decision-making with pure rewards and opportunity costs.**"

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ABSTRACT

Brain stimulation reward (BSR) has long been recognized as offering the best platform for quantitative psychophysical analyses of the nature of preference and choice. Particular illumination has been cast on effects of the value of the reward (i.e., the strength of the stimulation in the medial forebrain bundle) and the work requirements (i.e., the price, or the length of time a lever must be pressed) to get those rewards. However, theoretical accounts of these studies have been restricted in two ways: by being algorithmic rather than computational, and thus not offering a normative account, and by offering a molar rather than a molecular characterization of the subjects' choices, assessing overall rates of pressing rather than the detailed temporal topography of choice. We extend a semi-Markov model of appetitive vigour (Niv et al, 2007) to address both lacunæ. In the model, subjects can receive rewards from BSR or from leisure, and make stochastic, approximately optimizing choices of both whether to work or to rest, and for how long to do so. In an average reward setting, they pay an automatic opportunity cost for the time they allocate. We show that when the benefit of leisure increases non-linearly with leisure duration, it is possible to model in a qualitative manner many molecular features of choices. In particular, when the value of work exceeds that of leisure then the subjects will pre-commit to working for the whole price; furthermore, the distribution of leisure bouts post-reinforcement is roughly exponential with short means for high payoffs, gammas with means possibly exceeding the trial duration for low payoffs, and bimodal with short and long modes for medium payoffs.

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(27) "**tba**", Hadrien Orvoen, Sacha Bourgeois-Gironde

ABSTRACT

tba

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(28) "**Reward risk coding in the orbitofrontal cortex: An intracranial electrophysiological study in humans**"

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ABSTRACT

Introduction

The risk of an outcome, defined as the outcome variance, measures the unpredictability of the outcome (maximal for reward probability=0.5). Over the past decade, a large brain network has been shown to process reward risk in animals, particularly the midbrain dopaminergic region, ventral striatum, anterior insula, anterior cingulate cortex, hippocampus and orbitofrontal cortex (OFC) (Burker and Tobler, 2011; Doya, 2008; Dreher et al., 2006; Fiorillo et al., 2003; Hsu et al., 2005; Rushworth and Behrens, 2008; Schultz et al., 2008; Vanni-Mercier et al., 2009). In monkeys, a recent single-unit recording study directly demonstrated that OFC neurons track risk in predicted and received rewards (O'Neill and Schultz, 2010). Yet, it is still unknown whether population of neurons recorded with local field potentials (LFPs) explicitly encode risk information in humans' OFC. To address this question, we recorded OFC LFPs in epileptic patients implanted with depth electrodes while they learned to associate cues of different slot machines with distinct reward probabilities.

Methods

Six subjects were stereotaxically implanted with depth electrodes (0.8 mm multicontact cylinders, 2 mm long) as part of a presurgical evaluation. Four of them had right unilateral OFC implantation and the remaining two had left unilateral implantation. Unbeknownst to the subjects, five types of slot machines with different reward probabilities (P=0; 0.25; 0.5; 0.75 and 1) were presented in random order. Rewarded and unrewarded trials were pseudo-randomized. The subjects' task was to estimate on each trial the reward probability of each slot machine at the time of its presentation, based upon all the previous outcomes of the slot machine until this trial. The trials were self-paced and were composed of four different phases: (1) Presentation of slot machines phase (S1) (2) Delay period phase (1.5 s) (3) Outcome phase (0.5 s) (4) Reward/No reward delivery phase (1 s). The inter-trial interval was 1.5 ± 0.5 s. EEG signals were processed with EEGLAB (Delorme and Makeig, 2004). EEG was low-pass filtered (30 Hz) and visually inspected for the rejection of trials containing epileptic spikes and artifacts. Averaging and analysis of the EEG was performed on epochs of 3500 ms (- 500 to 3000 ms from the marker at the response), with a baseline correction from 500 ms to the response.

Results

Behavior: A multifactorial ANOVA performed on the percent of correct estimates of the probability of winning showed that both reward probability (P) and trial rank (R) influenced the percentage of correct estimations ($F_{4,20} = 69.18$, $p < 0.001$; $F_{19,95} = 28.21$; $p < 0.001$) and that the trial rank when learning occurred depended on reward probability ($F_{76,380} = 1.94$; $p < 0.001$).
Electrophysiology: Regardless of subsequent winning or not, a robust positive ERP emerged in the OFC at 244.7 (unrewarded trials) and 302.9 ms (rewarded trials) after the 2nd spinner stops. It peaked around outcome (when the 3d spinner stops) at 728.9±182.9ms (unrewarded trials) and 680.2±144.7 ms (rewarded trials) after the second spinner stops. Importantly, the mean peak ERP amplitude followed an inverted U-curve relationship with reward probability, varying non-linearly with reward probability, being maximal when reward uncertainty is highest (P=0.5), and minimal when reward uncertainty is lowest (P=0 and P=1), both for rewarded and unrewarded trials.

Conclusion

The present study provides the first direct intra-cranial recordings evidence that the human OFC codes reward risk during the phase of outcome expectation at a time scale of milliseconds, which cannot be observed with fMRI. This result extends to humans the coding of reward risk by OFC neurons in monkeys (O'Neill and Schultz, 2010). Local field potentials are of growing importance in neurophysiological investigations. They supplement neuronal recordings in monkeys by indexing activity relevant to EEG and BOLD fMRI signals. Recent reports suggest that LFPs reflect activity reflect a mixture of local potentials with 'volume conducted' potentials from distant sites (Kajikawa et Schroeder, 2011). These findings in humans show that LFPs recordings provide a useful complimentary approach to monkey recordings to study reward processing.

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(29) "**Spontaneous fluctuations in brain activity account for preference instability**", Raphaëlle Abitbol, Maël Lebreton, Guillaume Hollard and Mathias Pessiglione,

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ABSTRACT
According to economic theories, preference for one item over others reveals its rank value on a common scale. Supporting this theory, previous neuroimaging studies have identified brain regions automatically encoding such values across different elicitation methods (pleasantness ratings and binary choices). However, preference instability has been repeatedly observed, either over time or between different elicitation methods. On the other hand, electrophysiology as well as functional magnetic resonance imaging studies have shown that spontaneous brain activity can induce behavioural variability in perceptive, as well as in higher level cognitive tasks. In this study, we try to identify the neural substrates of preference instability, making the hypothesis that spontaneous variations in the activity of brain valuation regions affect the values assigned to choice options. During functional neuroimaging, participants rated the pleasantness of paintings, either in a musical or in a silent context. Subjects gave higher ratings to the paintings presented when the activity of the ventromedial prefrontal cortex (VMPFC) was in a higher state. Moreover, music pleasantness modulated VMPFC activity so as to influence the ratings attributed to paintings. These findings suggest that spontaneous variations in VMPFC activity do bias value judgments, which might explain some part of preference instability.

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(30) "**May the force be with you: neural mechanisms underlying social drives of effort production**" Raphaël Le Bouc and Mathias Pessiglione,

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ABSTRACT
Collaborative and competitive interactions are recurrent in social animals like humans. These social situations can modulate our motivation and enhance the amount of effort that we invest in a given task. It remains unclear whether social situations affect effort production because they change the personal utility of performing the task or if they represent a distinct class of motivational factors. Using functional magnetic resonance imaging we scanned participants while they played a two-player game comparing collaborative, individual and competitive situations of effort production. We found that motivation was primarily driven by effort marginal utility, which was reflected in brain regions classically involved in reward processing, such as the ventral pallidum. However, subjects who departed from utility maximization showed higher activation and higher grey matter density in brain regions classically involved in social cognition, such as the temporo-parietal junction. Thus, even if personal utility appeared as the main factor, truly social drives of effort production could still be observed, at least in a subset of participants.

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(31) "**Dissociable costs: effects of expected versus experienced task difficulty on effort allocation**"
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ABSTRACT
Long-run actions can be optimized relative to costs and benefits by alternating effort and rest periods. We proposed that decisions to cease and resume effort production are triggered online by a cost-evidence accumulation signal that reaches upper and lower bounds, respectively. Yet, how task difficulty affects the parameters (slopes and bounds) of the accumulation model remains unknown. Here, we tested healthy participants with three force production tasks in which the payoff was proportional to the time spent above a target force level. In the key dissociation task, difficulty (force level) was explicitly announced to subjects before each trial. However, this information was accurate in only half the trials, since the real force level was independently (and implicitly) manipulated. In the two other tasks, difficulty was either always explicit (and correct) or always implicit (with no cue). Results showed that when implicit, task difficulty affects effort but not rest duration, whereas when explicit, task difficulty affects both effort and rest durations. The model fit revealed how task difficulty impacts cost evidence monitoring: implicit costs modulated the accumulation slope during effort whereas explicit costs modulated the dissipation slope during rest.

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(32) "**Hemispheric dissociation of reward processing in humans: insights from deep brain stimulation**"
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ABSTRACT
Rewards have various effects on human behaviour and multiple representations in the human brain. Behaviourally, rewards notably enhance response vigour in incentive motivation paradigms and bias subsequent choices in instrumental learning paradigms. Neurally, rewards affect activity in different fronto-striatal regions attached to different motor effectors, for instance in left and right hemispheres for the two hands. Here we address the question of whether manipulating reward-related brain activity has local or general effects, with respect to behavioural paradigms and motor effectors. Neuronal activity was manipulated in a single hemisphere using unilateral deep brain stimulation (DBS) in patients with Parkinson's disease. Results suggest that DBS amplifies the representation of reward magnitude within the targeted hemisphere, so as to affect the behaviour of the contralateral hand specifically. These unilateral DBS effects on behaviour include both boosting incentive motivation and biasing instrumental choices. Furthermore, using computational modelling we show that DBS effects on incentive motivation can

predict DBS effects on instrumental learning (or vice versa). Thus, we demonstrate the feasibility of causally manipulating reward-related behaviour in humans, in a manner that is specific to a class of motor effectors but that generalises to different motivational processes. As these findings proved independent from therapeutic effects on parkinsonian motor symptoms, they might provide insight into DBS impact on non-motor disorders, such as apathy or hypomania.

Keywords: reinforcement learning, incentive motivation, hemispheric dissociation, deep brain stimulation, Parkinson's disease

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(33) "**Physical effort diminishes neural sensitivity to outcomes in ventral striatum**"

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Keywords: effort, action, reward, punishment

ABSTRACT

The acquisition of behaviour requires anticipation of demands and monitoring of outcomes. Prior to taking an action, we anticipate how much effort the action will require along with its expected benefits. After completing the action, we evaluate the affective outcomes achieved. It has been shown that anterior cingulate cortex (ACC) and dorsal striatum (dSTR) play a role in anticipation of effort and stimulus-response association, while ventral striatum (vSTR) signal outcome evaluative processes. Although the magnitude of effort is likely to influence outcome evaluation, it remains unclear if this is reflected neurally. Using functional magnetic resonance imaging (fMRI), we demonstrate that expending more effort diminishes ventral striatal signalling of the value of the outcome. We conducted a cue predictive task wherein participants anticipated and executed vigorous actions and were also presented with monetary outcomes for their actions. We manipulated actions to entail low or high effort. Importantly, outcome was designed to be probabilistic such that a proportion of the correct actions yielded outcomes with lower values. As previously shown the vSTR responded to better than expected outcomes. Importantly, this response to the outcomes is modulated by the level of effort. After exerting mild effort, outcome signalling in vSTR persists, but diminishes after large effort is exerted. Our findings provide a new insight into a neural modulation of effort on outcome evaluation at the vSTR.

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(34) "**Spatiotemporal structure of Anterior Cingulate Cortex activity contributes to behavioral adaptation coding -A spike-train metrics analysis approach-**"

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ABSTRACT

While monkeys perform a task alternating between behavioral adaptation and repetition of previous actions, firing rates in Anterior Cingulate Cortex (ACC) modulate with cognitive control levels (Quilodran et al., Neuron 57:314-25, 2008). However, little is known about whether ACC spike timing may participate to behavioral adaptation signaling, and how multiple unit activities may be jointly decoded. Additionally,

how a downstream network may decode the activity of ACC single neurons influenced by multiple factors remains unclear. We tested the hypothesis that temporal (or spatiotemporal) pattern matching coding may mediate information transmission in ACC.

We used spike-train metrics (Victor & Purpura, J Neurophysiol 76:1310-26, 1996) to decode ACC activity recorded in different task epochs (336 cells, 2 monkeys). We computed a similarity measure between any spike train and the activity patterns in different task epochs for classification. We explored different degrees of both timing sensitivity and distinction between spikes from different neurons for similarity computation, which led to different classification capacities.

We found that adapted timing sensitivity improves behavioral adaptation vs. repetition

classification of single unit spike trains. Optimal decoding occurs when accounting for spike times at a resolution <= 200 ms. Furthermore, spike-train metrics decoding of unitary discharges can be related to monkeys' response time. Regarding multiple unit decoding, we found that intermediate-to-complete distinction between spikes from two different units (as opposed to pooling them) can be optimal to improve classification compared to single unit. We also studied decoding of neurons whose activity is influenced by multiple variables. Our results suggest that a single temporal decoding strategy allows [behavioral adaptation] × [action] × [outcome] firing patterns to be readout.

Therefore, the spatiotemporal structure of spike trains appears to be relevant in this cognitive task. This opens the possibility for pattern matching-based decoding of ACC activity, potentially leading to adapted behavioral response.