

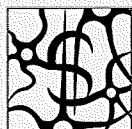
Meeting Program



5TH ANNUAL MEETING

HULL, MA

SEPTEMBER 27-30, 2007



SOCIETY FOR
NEUROECONOMICS

Schedule of Events for Neuroeconomics 2007, Hull, MA

~All meals will be served in the Surf Ballroom on the 2nd floor unless otherwise indicated below

~Workshops and main sessions will be in the Nantasket Room on the 1st floor

~Poster sessions will be in the Minot Room on the 1st floor

Thursday, September 27, 2007

1:30 - 5:00 pm Workshops in the Foundations of Neuroeconomics

The following two workshops will occur simultaneously, and you may choose which one you would like to attend

| | | |
|----------------|---|---|
| 1:30 - 3:00 pm | <u>Workshop I: Neuroscience for Economists</u> Computational Neuroanatomy Bruce Fischl—Harvard Medical School | <u>Workshop II: Economics for Neuroscientists</u> A birds eye view of the evolution of key methodological aspects of experimental economics Guillaume Frechette—New York University |
| | | |
| 3:00 - 3:30 pm | Coffee Break | |
| 3:30 - 5:00 pm | Neuroimaging for Neuroeconomics Randy Buckner—HHMI, Harvard University | Strategies for economic experiments: Some pitfalls and highlights Muriel Niederle—Stanford University |
| 6:00 pm | Reception—Cash Bar | |
| 7:00 pm | Buffet Dinner | |

Friday, September 28, 2007

8:00 - 8:45 am Continental Breakfast

8:45 - 9:00 am Liz Phelps Welcome & Opening Remarks

Social & Contextual Factors in Decision Making

| | | | |
|------------------|----------------|--|--|
| 9:00 - 9:30 am | Ming Hsu | Neural basis of moral decision making: Tradeoffs between equity and efficiency | Ming Hsu, Cedric Anen, Steven Quartz |
| 9:35 - 10:05 am | Michael Hardin | How money talks to the brain | Monique Ernst, Michael G. Hardin, and Daniel S. Pine |
| 10:10 - 10:40 am | Bernd Weber | Social comparison influences reward-related activity in the human ventral striatum | Bernd Weber, Klaus Fliessbach, Thomas Dohmen, Uwe Sunde, Peter Trautner, Christian Elger, Armin Falk |
| 10:40 - 12:40 am | | Poster Session I | |
| 12:45 - 1:45 pm | Lunch | | |
| 1:45 - 3:45 pm | | Poster Session II | |

Risk

| | | | |
|----------------|-----------------------------|---|---|
| 4:00 - 4:30 pm | Peter N. C. Mohr | Risk-value trade-off in investment decisions | Peter N. C. Mohr, Guido Biele, Lea Krugel, Shu-Chen Li, Hauke Heekeren |
| 4:35 - 5:05 pm | Benjamin Hayden | Understanding the role of salience in risky decision-making | Benjamin Y. Hayden, Allison N. McCoy, Amrita Nair, and Michael L. Platt |
| 5:10-5:40 pm | Ifat Levy | Neural correlates of subjective value under risky and ambiguous decision-making | Ifat Levy, Aldo Rustichini, and Paul W. Glimcher |
| 5:45 - 6:15 pm | Mathieu d'Acremont | Risk prediction in the human brain: A functional neuroimaging study | d'Acremont, M., Lu, Z.-L., Li, X., and Bechara, A. |
| 7:00 pm | Dinner—New England Clambake | | Hull Yacht Club* |

*Dinner is offsite—shuttles will be provided to those who don't have transportation

Saturday, September 29, 2007

8:30 – 9:30 am Continental Breakfast
Women in Neuroeconomics breakfast Rafael's

Aversive Processing

| | | | |
|------------------|------------------|---|---|
| 9:30 – 10:00 am | Mauricio Delgado | Aversive conditioning with secondary reinforcers: Fear of losing money? | Mauricio R. Delgado, Rita L. Jou, Elizabeth A. Phelps |
| 10:05 – 10:35 am | Scott Huettel | Unattractive faces and financial losses activate similar brain regions | David Smith, Benjamin Hayden, Michael Platt, & Scott Huettel |
| 10:40 – 11:10 am | Charles Noussair | Neurobiological regret and rejoice functions for aversive outcomes | Gregory S. Berns, C. Monica Capra, Pammi V.S. Chandrasekhar, Charles Noussair |

11:10 – 11:40 am Coffee Break

Cognition & Economic Behavior

| | | | |
|------------------|---------------|--|----------------------------------|
| 11:40 – 12:10 am | Ellen Furlong | Why is the parietal cortex involved in economic decision making? | Ellen E. Furlong & John E. Opfer |
|------------------|---------------|--|----------------------------------|

Value & Preference

| | | | |
|------------------|-----------------|---|---|
| 12:15 – 12:45 am | Greg S. Corrado | fMRI in monkeys and humans engaged in a foraging task | G. S. Corrado, L. P. Sugrue, J. R. Brown, N. K. Logothetis, W. T. Newsome |
|------------------|-----------------|---|---|

12:45 – 1:45 pm Lunch

| | | | |
|----------------|--------------------|---|---|
| 1:30 – 2:10 pm | Hilke Plassmann | Marketing actions can modulate neural representations of experienced utility | Hilke Plassmann, John O'Doherty, Baba Shiv, and Antonio Rangel |
| 2:15 – 2:55 pm | Daniel Krawczyk | The emergence of product preferences: from early visual processing to preference-based choice | Daniel C. Krawczyk, Conrad Capili, Anson Chu, Jonathan Coker, Cressy Wang, & Julian Jamison |
| 3:00 – 3:30 pm | John R. Monterosso | Delay discounting based on activation in the ventral striatum | John R. Monterosso, George W. Ainslie, Edythe D. London |

Evening free, dinner on your own

Sunday, September 30, 2007

7:30 – 8:30 am Continental Breakfast

Trust and Cooperation

| | | | |
|------------------|--------------------|---|---|
| 8:30 – 9:00 am | Tania Singer | Empathic brain responses, prosocial behaviour and effects of oxytocin | Tania Singer |
| 9:05 – 9:35 am | Ernst Fehr | Testosterone as a license to unfairness | Eisenegger Christoph, Snozzi Romana, Naef Michael, Heinrichs Markus, Ernst Fehr |
| 9:40 – 10:10 am | Griet Emonds | Comparing the neural basis of mixed-motive versus coordination games | G. Emonds, C. Declerck, C. Boone, P. Parizel, E. Vandervliet |
| 10:15 – 10:45 am | Wouter Van den Bos | Development of cooperation and competition: changes in brain mechanisms underlying social interaction | van den Bos, W., van Dijk, E., Westenberg, P.M., Crone, E. A. |

11:00 am Checkout

Corrected Saturday Schedule

Saturday, September 29, 2007

| | | |
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| 10:05 – 10:35 am | Scott Huettel | To satisfy or maximize? Neural predictors of the loss-aversion heuristic in decision making | Vinod Venkatraman, John Payne, and Scott Huettel |
| 10:40 – 11:10 am | Charles Noussair | Neurobiological regret and rejoice functions for aversive outcomes | Gregory S. Berns, C. Monica Capra, Pammi V.S. Chandrasekhar, Charles Noussair |

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Evening free, dinner on your own

Poster Session I, Friday 10:40 am – 12:40 pm

| Authors | Title |
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| Daniel R. Burghart, William T. Harbaugh, Ulrich Mayr | Consequence and conflict: The net effect on mental effort |
| Nina Curley, Peter Sokol-Hessner, Ming Hsu, Mauricio Delgado, Colin Camerer, Elizabeth Phelps | Regulating loss aversion: A physiological correlate of the relative overvaluation of losses |
| Catherine Hartley, Elizabeth A Phelps | Brain structure correlates of sensitivity to anticipated aversive outcomes |
| Daniela Schiller, Jonathan B Freeman, Jason P Mitchell, Jim S Uleman, Elizabeth A Phelps | Assigning value to people – Role of posterior cingulate cortex and amygdala |
| Peter Sokol-Hessner, Ming Hsu, Nina Curley, Mauricio Delgado, Colin Camerer, Elizabeth A Phelps | Thinking like A trader: Distinct neural correlates of loss aversion and its intentional regulation |
| Fiery Cushman, Anna Dreber, Ying Wang, Jay Costa | The interaction of intentions and consequences in punishment and reward: Evidence from an economic game |
| Adam Kepecs, Naoshige Uchida, Hatim Zariwala, Zachary F. Mainen | Neural representation and behavioral impact of decision confidence |
| Kaisa Hytönen, Vasily Klucharev, Ale Smidts, Ivan Toni | The effect of prior probability on decision making |
| Vasily Klucharev, Kaisa Hytönen, Ale Smidts, Guillen Fernandez | Social decisions & social norms: A neurobiological model |
| Jyrki Suomala, Markus Kivikangas, Teemu Santonen | Self-relevance goal as reference point |
| Nai-Shing Yen, Ying-Ru Lai, Yin-Fang Chang, Tzu-Hsin Yeh, Kuan-Hua Chen | The effect of expectancy on feedback-related negativity |
| Hui-Kuan Chung, Nai-Shing Yen, Kuan-Hua Chen, Tzu-Hsin Yen, Shih-Ping Hsiu | Deck C and D are preferred even when expected values in the Iowa Gambling Task are controlled |
| Yao-Chu Chiu, Ching-Hung Lin | Is deck C an advantageous deck in the Iowa Gambling Task? |
| Yao-Chu Chiu, Ching-Hung Lin | Is deck E an advantageous deck in the inverted Iowa Gambling Task? |
| Ching-Hung Lin, Yao-Chu Chiu | Gender difference of sensitivity for gain-loss frequency in the Soochow gambling task |
| Ching-Hung Lin, Yao-Chu Chiu, Jong-Tsun Huang | Is decision-maker sensitive to expected value in the dynamic-uncertain gambles? |
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| Darrell A. Worthy, W. Todd Maddox, Arthur B. Markman | Regulatory fit effects in a gambling task |
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| Wouter van den Bos, Jian Li, Tatiana Lau, Samuel M. McClure, Jonathan D. Cohen, P. Read Montague | Social influences on bidding in common value auctions and the Winner's Curse |
| Gregory S. Berns, C. Monica Capra, Sara Moore, Charles Noussair | The neurobiological effect of social information on preferences and risk attitudes in the adolescent brain |
| Peter Kenning, Peter Mohr, B. Severin, Harald Kugel, Wolfram Schwindt, Michael Deppe | The origins of trust |
| Vera B. Morhenn, Jang Woo Park, Elisabeth Piper, Paul J. Zak | Monetary sacrifice among strangers is mediated by endogenous oxytocin release after physical contact |

Poster Session II, Friday 1:45 pm – 3:45 pm

| Authors | Title |
|---|--|
| Konstanze Albrecht, Kirsten G. Volz, Matthias Sutter, David I. Laibson, D. Yves von Cramon | The neural basis of intertemporal choice for self and other |
| Gregory S. Berns, C. Monica Capra, Sara Moore, Charles Noussair | The neurobiological effect of social information on preferences and risk attitudes in the adolescent brain |
| Antoine Bruguier, Steve Quartz, Peter Bossaerts | Paracingulate cortex activates when reading the "mind" of financial markets with potentially beneficial or harmful insider information |
| Andrew Caplin, Mark Dean, Paul W. Glimcher, Robb Rutledge | Dopamine and reward prediction error: Theory and evidence |
| Eric E. J. DeWitt, Mark Dean, Paul W. Glimcher | Learning in uncertain environments: Measuring human performance against a normative benchmark |
| Joseph W. Kable, Paul W. Glimcher | Constraining the neural algorithm for intertemporal choice |
| Amy L. Krain, Kristin Gotimer, Ifat Levy, Paul W. Glimcher | Measuring aversion to risk and ambiguity in children and adolescents |
| Kenway Louie, Lauren Grattan, Paul W. Glimcher | The effect of non-chosen choices: relative reward coding in parietal area LIP |
| Robb B. Rutledge, Brian Lau, Stephanie C. Lazzaro, Catherine E. Myers, Mark A Gluck, Paul W. Glimcher | Parkinson's disease and dopaminergic drugs modulate human reinforcement learning rates |
| Bailey House, Laurie Santos | The origins of anchoring and adjustment: Biased numerical estimations in non-human primates |
| Daniel Houser, Daniel Schunk, Erte Xiao | Combining brain and behavioral data to improve Econometric Policy Analysis |
| Yang-Tae Kim, Hansem Sohn, Jaeseung Jeong | Impairments in decision-making under ambiguity and risk in alcohol dependence |
| Jeongbin Kim, Hansem Sohn, Kyongsik Yun, Jaehyun Lim, Wonjoon Kim, Jaeseung Jeong | Neuropsychological mechanisms of odd-pricing effect |
| Hansem Sohn, Jaeseung Jeong | Differential neural mechanisms underlying temporal discounting of financial gain and loss |
| Seongmin Park, Kyongsik Yun, Jaeseung Jeong | Neuroimaging study for the effect of painting's information on aesthetic preference for contemporary paintings |
| Jeff T. Klein, Michael L. Platt | Ventral striatum signals both social and nutritive rewards |
| Christian C. Luhmann, Marvin M. Chun, Doojin Yi, Daeyeol Lee, Xiao-Jing Wang | Dissociating uncertainty and delay in inter-temporal choice |
| Laura N. Martin, Dominic S. Fareri, Mauricio R. Delgado | The influence of emotion regulation strategies on risky decision making |
| Anthony J. Porcelli, Mauricio R. Delgado | Acute stress modulates risk sensitivity in Financial decision making |
| W.F. Hoffman, D.L. Schwartz, M.S. Huckmans, B.H. McFarland, A.A. Stevens, Suzanne H. Mitchell | Amygdala activation during delay discounting in abstinent methamphetamine dependent individuals |
| Carolin Neuhaus, Ivo Bischoff, Bernd Weber | The utility of voting: Neural correlates of expressive voting |
| Andrew S. Hart, Julia C. Lemos, Matthew J. Wanat, Paul E. M. Phillips | Stress, drugs, dopamine and risk taking |
| Kerstin Preuschoff, John O'Doherty, Peter Bossaerts | Decision making under ambiguity: Behavior and neurobiology |
| Dharol Tankersley, Zoe Englander, Scott A Huettel | Other-regarding behavior and neural systems of social perception |
| Bethany Weber, Scott Huettel | The neural substrates of probabilistic and intertemporal decision making |
| Shih-Wei Wu, Laurence T. Maloney | The use of probability in decision making under risk compared to an equivalent motor task |
| G Elliott Wimmer, Camelia M Kuhnen, Piotr Winkielman, Brian Knutson | Nucleus accumbens activation mediates the influence of incidental reward cues on financial risk-taking |

Thursday, September 27, 2007

Workshop I: Neuroscience for Economists

Part 1

1:30 -3:00 pm

**Computational Neuroanatomy
Bruce Fischl—Harvard Medical School**

In this talk I will discuss the construction and utility of neuroanatomical models derived from magnetic resonance imaging (MRI) data. These models have been used extensively in the analysis of anatomical changes underlying a variety of disorders, but also facilitate the use of an array of functional analysis techniques that would otherwise not be available. These techniques take advantage of the strong relationship between structure and function in the human brain, and can be broadly divided into surface-based methods for the analysis of cortical effects, and volumetric techniques for non-cortical analysis.

Cortical structures (particularly the cerebral cortex) are typically highly folded, thin sheets of gray matter. Functionally, the cerebral cortex has been shown to have a "columnar" architecture. This functional architecture is somewhat mirrored by the structural organization into histologically defined cortical areas, such as the famous cortical parcellation of Korbinian Brodmann (1909). For these reasons, we construct surface-based models for the analysis of cortical properties. The cortical models can then be deformed for morphometry, visualization and registration purposes. In particular, the strong correlation between functional properties and folding patterns allows surface-based inter-subject registration to provide significantly greater functional power and specificity of localization of effects than more standard volumetric techniques.

A different set of techniques have been developed for the construction of models of subcortical structures. Here we utilize volumetric algorithms to model intrinsically volumetric structures such as the caudate, putamen, ventricular system, etc.... The result is a complete description of all macroscopically visible neuroanatomical structures that facilitates the probing of hypotheses such as "is the average timecourse in the hippocampus correlated with my stimulus", or "is the anterior cingulate baseline activity correlated with activity in the amygdala".

Finally, I will discuss recent techniques that allow us to make strong inferences as to the true (microscopically defined) identity of the location of cortical effects, facilitating the comparison of effects across subjects and studies.

Part 2

3:30 – 5:00 pm

**Neuroimaging for Neuroeconomics
Randy Buckner—HHMI, Harvard University**

Functional brain imaging methods provide tools for exploring brain systems important to economic decisions. In this presentation, the basis of these methods will be discussed in the context of how they can be employed for neuroeconomics.

Workshop II: Economics for Neuroscientists

Part 1

1:30 -3:00 pm **Guillaume Frechette**
A birds eye view of the evolution of key methodological aspects of experimental economics

The lecture will highlight methodological aspects that have become part of the standard design in experimental economics. Topics such as the use of incentives, incentive compatibility, belief elicitation, inducing of risk preference, etc will be covered. They will be presented through examples which will outline the history and evolution of experimental economics. The papers covered test economic models, mainly game theoretic ones.

Part 2

3:30 – 5:00 pm **Muriel Niederle**
Strategies for economic experiments: Some pitfalls and highlights

Topics in economic experiments that overlap with psychology studies, and how the techniques, and concerns in economics differ. Experiments on gender, beauty, and competition, with some general design lessons.

Friday, September 28, 2007

8:00 – 8:45 am Continental Breakfast

8:45 – 9:00 am Liz Phelps Welcome & Opening Remarks

Social & Contextual Factors in Decision Making

9:00 – 9:30 am Ming Hsu Neural basis of moral decision making: Tradeoffs between equity and efficiency Ming Hsu, Cedric Anen, Steven Quartz

9:35 – 10:05 am Michael Hardin How money talks to the brain Monique Ernst, Michael G. Hardin, and Daniel S. Pine

10:10 – 10:40 am Bernd Weber Social comparison influences reward-related activity in the human ventral striatum Bernd Weber, Klaus Fliessbach, Thomas Dohmen, Uwe Sunde, Peter Trautner, Christian Elger, Armin Falk

10:40 – 12:40 am Poster Session I

12:45 – 1:45 pm Lunch

1:45 – 3:45 pm Poster Session II

Risk

4:00 – 4:30 pm Peter N. C. Mohr Risk-value trade-off in investment decisions Peter N. C. Mohr, Guido Biele, Lea Krugel, Shu-Chen Li, Hauke Heekeren

4:35 – 5:05 pm Benjamin Hayden Understanding the role of salience in risky decision-making Benjamin Y. Hayden, Allison N. McCoy, Amrita Nair, and Michael L. Platt

5:10-5:40 pm Ifat Levy Neural correlates of subjective value under risky and ambiguous decision-making Ifat Levy, Aldo Rustichini, and Paul W. Glimcher

5:45 – 6:15 pm Mathieu d'Acremont Risk prediction in the human brain: A functional neuroimaging study d'Acremont, M., Lu, Z.-L., Li, X., and Bechara, A.

7:00 pm Dinner—New England Clambake Hull Yacht Club*

*Dinner is offsite—shuttles will be provided to those who don't have transportation

Title: Neural Basis of Moral Decision-Making: Tradeoffs between Equity and Efficiency

Authors: Ming Hsu, Cedric Anen, Steven Quartz

Institution: Hsu: University of Illinois at Urbana-Champaign
Anen & Quartz: California Institute of Technology

Email for Corresponding Author(s): minghsu@uiuc.edu

Web address URL for a paper (if available):

Abstract text (fill no more than this page)

Recent interdisciplinary work in neuroscience and moral philosophy has tried to reduce the study of moral decision-making to its neurobiological foundations. We contribute to this literature by studying moral decision-making from an economic perspective. To this end, we introduced a novel task to investigate the behavioral and neural mechanisms of tradeoffs between efficiency and equity. Unlike previous experiments, our task (i) employs real consequences, (ii) partitions the temporal ordering of decisions, and (iii) parametrically modulate relative equity and efficiency of the outcomes.

Behaviorally, we estimated the level of subjects' inequity aversion using their choices, under the assumption that subjects tradeoff between efficiency and equity linearly. fMRI data showed that putamen is the unique region significantly correlated with efficiency, whereas the insula encodes for relative equity levels. Finally, the caudate head is unique region that is significantly correlated with both equity and efficiency. Furthermore, activity in the insula and caudate head are significantly correlated with the behavioral inequity aversion parameter. These results show that the neural mechanism of moral decision-making has important commonalities and differences with those involved in individual and interpersonal decision-making.

Title: How money talks to the brain

Authors: Monique Ernst, Michael G. Hardin, and Daniel S. Pine

Institution: Mood and Anxiety Disorders Program, National Institute of Mental Health

Email for Corresponding Author(s): ernstm@mail.nih.gov

Web address URL for a paper (if available):

Abstract text (fill no more than this page)

The emotional significance of an event depends on the context in which it occurs. For example, not losing money in a downward stock market is experienced as a gain, while not winning money in an upward stock market is experienced as a loss. These processes involve a number of neural regions, including the nucleus accumbens (NAcc), orbital frontal cortex (OFC), medial prefrontal cortex (mPFC), amygdala, and insula. While these regions respond to both appetitive and aversive outcomes, converging evidence suggests some degree of specialization with regard to emotional valence. For example, NAcc, OFC, and mPFC are traditionally associated with appetitive outcomes and approach behavior, while amygdala and insula are associated with aversive outcomes and withdrawal behavior. The purpose of the current study was to examine neural responses in these regions to monetary outcomes that vary in emotional valence depending on the context in which they were experienced.

Eighteen healthy adults played a monetary decision making game in both positive and negative economic contexts during fMRI scanning. A whole brain analysis contrasting [Favorable-Unfavorable] outcomes in a Positive context (gains vs. no-gains) with [Favorable-Unfavorable] outcomes in a Negative context (no-losses vs. losses) confirmed involvement of a network including the NAcc, OFC, mPFC, amygdala, hippocampus, and insula. The decomposition of this contrast into finer analyses revealed two distinct patterns of neural activation. Specifically, a greater increase in BOLD response was observed in the NAcc, OFC, and mPFC in response to the Positive context, while a greater increase in BOLD response was observed in the amygdala and insula in response to the Negative context.

These findings indicate that the network including NAcc, OFC, mPFC, amygdala, and insula shows different patterns of engagement as a function of valence. Consistent with a commonly reported appetitive/ reward related role, the NAcc, OFC, and mPFC appear to be most responsive to Favorable outcomes presented in a Positive context. Similarly, the amygdala and insula appear to be most responsive to Unfavorable outcomes that occur in a Negative context. Additional discussion will be provided regarding secondary analyses on the relative effects of valence and salience on activation of this network.

Title: Social comparison influences reward-related activity in the human ventral striatum

Authors: Bernd Weber, Klaus Fliessbach, Thomas Dohmen, Uwe Sunde, Peter Trautner, Christian Elger, Armin Falk

Institution: life&brain Research Center Bonn, Department of NeuroCognition | Imaging
Department of Economics, University of Bonn

Email for Corresponding Author(s): bweber@lifeandbrain.com

Web address URL for a paper (if available):

Abstract text (fill no more than this page)

Whether inter-individual comparisons affect individual well-being is of central importance for understanding behavior in any social environment. Traditional models of behavior, in particular economic models of human behavior, mostly focus on the role of absolute rewards, while behavioral evidence suggests that social comparisons influence incentives and decisions. We investigated the impact of social comparisons on reward related brain activity using functional MRI. While being scanned in two adjacent MRI scanners, pairs of two subjects had to simultaneously and repeatedly perform a simple estimation task that entailed monetary rewards in case of correct performance. Both absolute and relative payments were varied experimentally, and the corresponding neural responses were analyzed. The results show that, while keeping a subject's absolute payment constant, a variation in the comparison subject's payment affects BOLD responses in the ventral striatum. Our results i) show that ventral striatal responses to rewards are not only explained by a comparison of expected and received rewards but instead integrate immediate contextual information and ii) provide neurophysiological evidence for the importance of social comparison on reward processing in the human brain.

Poster Session I, Friday 10:40 am – 12:40 pm

| Authors | Title |
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| Daniela Schiller, Jonathan B Freeman, Jason P Mitchell, Jim S Uleman, Elizabeth A Phelps | Assigning value to people – Role of posterior cingulate cortex and amygdala |
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| Peter Kenning, Peter Mohr, B. Severin, Harald Kugel, Wolfram Schwindt, Michael Deppe | The origins of trust |
| Vera B. Morhenn, Jang Woo Park, Elisabeth Piper, Paul J. Zak | Monetary sacrifice among strangers is mediated by endogenous oxytocin release after physical contact |

Title: Consequence and conflict: The net effect on mental effort

Authors: Daniel R. Burghart¹, William T. Harbaugh¹, Ulrich Mayr²

Institution: 1- Economics Department, University of Oregon
2- Psychology Department, University of Oregon

Email for Corresponding Author(s): dburghar@uoregon.edu

Web address URL for a paper (if available): N/A

Abstract text (fill no more than this page)

There are two potential effects at work when people exert mental effort associated with choices: consequence and conflict. The "consequence effect" will be large if the utility difference between alternatives is sizeable, since the net benefits of a well-thought-out decision are high. In this instance however, the "conflict effect" will be small because a large difference in utility means the preferred alternative is more obvious, and the value from additional mental effort is low. Economic models of choice tend to focus on outcomes and the consequence effect. In contrast, the conflict effect is emphasized in cognitive neuroscience, where the focus is on neural processes. Because these two effects indicate that the intensity of neural activity will move in opposite directions we cannot predict, a priori, the change in mental effort as alternatives get farther apart in utility terms.

It is interesting to know which effect dominates because mental effort, usually associated with prefrontal activity, is a scarce good with many uses besides making a particular choice. To evaluate this question we examined choice and fMRI data from an experiment where people could choose to contribute money to a public good or keep it for themselves (Harbaugh, Mayr, & Burghart, 2007). Because our task design included orthogonal variations in conflict and consequences it provided us with the opportunity to characterize the representation of these potential influences on mental effort. To this end, we estimated individual utility functions from choices, and predicted the difference in utilities between available alternatives. We then investigated neural activity as a function of these individually defined utility differences. Our initial analyses show less activity in mid-frontal regions when a utility difference is large, suggesting that for simple choices between cash and a charitable contribution, the conflict effect dominates the consequence effect: people appear to exert more mental effort when the available alternatives produce similar utility outcomes. We also investigate how the location of activation associated with the consequence and conflict effects differs across the pre-frontal cortex.

Title: Regulating Loss Aversion: A Physiological Correlate of the Relative Overvaluation of Losses

Authors: Curley, Nina(1), Sokol-Hessner, Peter(1), Hsu, Ming(3), Delgado, Mauricio(4), Camerer, Colin(5), Phelps, Elizabeth(1,2)

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Abstract text (fill no more than this page)

Loss aversion, formalized with the parameter λ , describes the multiplicative overvaluation of losses relative to gains. While many studies have confirmed the existence of loss aversion on a group level, few, if any, have quantifiably demonstrated or manipulated loss aversion on an individual level.

We developed a set of 140 monetary choices to robustly recover behavioral choice parameters for individuals. After an initial endowment of \$30, participants made choices between risky binary gambles and guaranteed outcomes. From these choices we were able to reliably recover accurate value parameters and demonstrate individuals' loss aversion.

We used this paradigm to investigate the effect of intentional cognitive regulation strategies on choice behavior. In the first of two sessions, participants completed two identical sets of choices. One set's strategy encouraged the bracketing of choices ("portfolio" approach), while the other set was made considering each choice in isolation ("one-choice" approach). The "portfolio" strategy reliably decreased estimates of λ within-subjects.

During the second session, participants made choices while galvanic skin response (GSR) was recorded. When using the "one-choice" strategy, participants showed higher arousal per dollar to losses than gains. Greater arousal to losses relative to gains correlated positively with behavioral loss aversion. Furthermore, the group of participants who had a significant decrease in λ from the "one-choice" to the "portfolio" condition showed a corresponding significant decrease in arousal to losses relative to gains. The group of participants who did not show a significant decrease in λ showed no significant physiological effect.

The present study demonstrates the robust effect of an intentional cognitive regulation strategy in decreasing both behavioral and correlating physiological measures of sensitivity to losses relative to gains.

Title: Brain structure correlates of sensitivity to anticipated aversive outcomes

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Abstract text (fill no more than this page)

Recent research has tied individual differences in one's sensitivity to potential aversive outcomes to choice behavior under risk (Berns et al., 2006, Paulus et al., 2003). This increased sensitivity is indexed by relatively larger physiological and neural responses during the anticipation of potentially aversive events. However, the neural mechanisms underlying these individual differences are not well understood. In this study, we tested the hypothesis that structural differences in regions involved in affective processing might be correlated with individual sensitivity to the possibility of negative outcomes. We examined whether cortical thickness in anterior cingulate cortex, medial prefrontal cortex, and insular cortex, as well as amygdalar volume are correlated with the magnitude of individuals' arousal responses and their ability to regulate those responses via intentional emotion regulation.

We employed a partial-reinforcement fear-conditioning paradigm in order to assess subjects' arousal responses during the anticipation of a possible shock. During conditioning, the CS+ (a blue square) was paired with a shock on a subset of trials, while the CS- (a yellow square) was never paired with a shock. Subjects were asked to either "attend" to or "regulate" their response to the presented stimuli. Skin conductance responses were obtained for each subject as a behavioral measure of arousal in both the "attend" and "regulate" conditions. We obtained structural MRI data from each subject in order to generate the cortical thickness measurements, and conducted both a region-of-interest and a whole-brain analysis to identify regions where morphometric measurements correlated with conditioned fear responses.

Individual differences in cortical thickness in the posterior insula and rostral anterior cingulate cortex were positively correlated with the magnitude of the arousal response during the "attend" condition. Notably, thickness in these regions did not correlate with arousal magnitude during intentional regulation. The magnitude of reduction of the arousal response during the "regulate" condition correlated individuals' cortical thickness in a region of the medial frontal gyrus. Research suggests that the insula is critically involved in the representation of aversive experience, with the posterior insula responding primarily to the anticipation and experience of viscerally noxious stimuli and anterior insula responding additionally to more abstract psychologically aversive stimuli. Consistent with this research, a recent study found that insula activity predicted subsequent risk-averse behavior during decision-making (Kuhnen and Knutson, 2005). The data in this experiment suggest a structural basis for differences in sensitivity to anticipated aversive experience, but illustrate that intentional cognitive regulation strategies can serve to override these prepotent behavioral biases.

Title: Assigning Value to People - Role of Posterior Cingulate Cortex and Amygdala

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The valuation system in the brain has been a central target of neuroeconomics research in recent years. A basic premise in economic theories is that the value assigned to rewards is essentially subjective and reflects personal preferences. In addition, a predominant feature of a social economic exchange is the representations of others' mental states, required, for example, for social agency assignment and outcome credit. However, another key feature that has been relatively neglected is the underlying evaluation of another human being. Such evaluation is a prerequisite for any decision or action in a social context and is often being performed rapidly and based on very few and at times conflicting pieces of information.

The present study sought to look beyond evaluations of inanimate reinforcers (e.g. monetary rewards) or others' actions (e.g. monetary investments), and investigate the process of evaluating others in a social context. To this end, we measured BOLD signals during exposure to different person profiles. Each profile consisted of varying degrees of positive and negative information. In each profile presentation, there was a gradual transition from positive to negative information or vice versa. Subjects were requested to form an impression of each person using an evaluation scale. These responses were used to determine which information was subjectively significant, influencing their impressions (evaluation-relevant), and which was disregarded (evaluation-irrelevant). We then looked for brain areas responding differentially to these different types of information.

We found that the posterior cingulate cortex (PCC) was selectively engaged during the presentation of the information that was consistent with subsequent impression (evaluation-relevant). Importantly, this activation corresponded only to information that was subjectively meaningful and not to its objective (positive or negative) valence as pre-defined in a pretest. For example, stronger responses in PCC were seen during the presentation of a positive segment of a person profile, as opposed to the negative segment, only when the subsequent evaluation was positive as well. Another area showing a similar pattern of results was the amygdala, an area that has long been implicated in assigning value to neutral stimuli predictive of motivationally significant outcomes.

Further analysis revealed that amygdala responses scaled with the level of evaluation, i.e., the higher the evaluation, the higher the responses to the corresponding segment of information (either positive or negative). Interestingly, such correlation was seen in the PCC only for positive evaluations. Activation in PCC has been previously shown to scale with the subjective value of immediate and delayed rewards as well as with other people's actions in a social exchange. The present result is consistent with these findings and further suggests that the PCC encodes primarily positive subjective value of social information subsequently used for evaluations of social others.

Taken together, it appears that evaluations of others is done by way of assigning subjective value to the segments of information they socially exhibit. This integrated activity, carried out predominantly by the amygdala and PCC, might provide critical information on the social context for decision making in economic exchanges.

Title: Thinking Like A Trader: Distinct Neural Correlates of Loss Aversion and its Intentional Regulation

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Abstract text (fill no more than this page)

Loss aversion describes the overvaluation of losses relative to gains. Its existence has been confirmed in the average behavior of groups, but few, if any, studies have produced quantifiable estimates of individuals' loss aversion, allowing precise within-subject analyses and description of individual variability. As a result, most analyses of neural correlates of loss aversion have failed to take account of sizable individual differences.

We developed a set of 150 monetary choices that allow the accurate recovery of a range of parameter values describing individuals' choices. After an initial endowment of \$30, participants made choices between risky binary gambles and guaranteed outcomes, receiving feedback immediately after each choice. 10% of all outcomes were randomly selected and realized at the end of the study. Participants' choices permitted accurate estimation of value function parameters, including loss aversion.

We used this task to examine the effects of intentional cognitive regulation strategies, by asking participants to complete two identical sets of choices. One set was performed with a strategy emphasizing choices in isolation ("one-choice"), and one set was completed with a strategy emphasizing the contextual bracketing of choices ("portfolio"). The "portfolio" approach reliably and selectively decreased participants' loss aversion.

Participants underwent fMRI during the task to allow us to simultaneously capture neural correlates of their quantified behavior. Using whole-brain correlation analyses, we identified distinct neural correlates of behavioral loss aversion including dorsal anterior cingulate, anterior insula, and amygdala. We observed different patterns of correlations in these regions across the "one-choice" and "portfolio" strategies, indicating potential neural substrates of the intentional cognitive strategies. Linear contrasts also identified task-related activity in the caudate, putamen, and medial prefrontal cortex, but these areas did not correlate significantly with loss aversion and its strategic manipulation.

This study demonstrates the reliable and precise effects of an intentional regulation strategy on quantified loss aversion as measured behaviorally and neurally, and shows distinct neural substrates of the sensitivity to losses relative to gains.

Title: The interaction of intentions and consequences in punishment and reward: evidence from an economic game

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Abstract text (fill no more than this page)

Several recent studies suggest a critical role for perceived intentionality in spiteful punishment. Specifically, people are more likely to punish a stingy allocation when the allocation is made intentionally than when the allocation is not an intentional act (Falk, Fehr and Fischbacher 2003; Falk, Fehr & Fischbacher 2000), and the neural substrates of this phenomenon have been explored using standard economic methods (Sanfey, Rilling et al 2003). These findings have been taken to suggest that intentions dominate consequences as the determinant of spiteful punishment in the context of economic games. However, psychological research suggests that moral judgment depends on a more complex interaction of information about both intentions and consequences, and that in certain conditions consequences can play a dominant role (Cushman in press). The neural mechanisms supporting this integration have also been investigated using standard psychological methods (Young, Cushman et al). Unfortunately, divergent methodologies have hindered crosstalk between these two literatures: economists have not designed studies that directly assess the interaction between consequences and intentions, while psychologists have primarily relied upon surveys about hypothetical scenarios rather than economic games with monetary consequences.

A simple economic game was constructed to attempt to link psychological findings on the integration of intentions and consequences with the methodologies standard to behavioral economics. Player 1 allocates \$10 between himself and Player 2 by choosing one of three dice to roll. The dice differed in their probabilities of yielding stingy, fair or generous allocations, however, any individual die can yield any outcome with nonzero probability. Player 2 observes which die is chosen (an indication of player 1's intentions) and how it comes up (which determines the consequences). Player 2 then responds by adding to or subtracting money from Player 1's payoff. This allows us to assess how information about both Player 1's intentions and the consequences of Player 1's roll interact to determine rewards and punishments. Control conditions were also run in which Player 1 had either full intentional control over the allocation by directly specifying it, or had absolutely no intentional control over the allocation because only a single die was available with equal probabilities of each outcome.

The results of this study suggest a stronger role for consequences than intentions in determining the response of player 2, although both factors play a significant role. Player 2 tends to punish stingy allocations even when Player 1 intended to be generous, and Player 2 tends to reward generous allocations even when Player 1 intends to be stingy. Comparisons to the control conditions indicate that the role of consequences is not limited to inequity aversion. These results challenge the assumption derived from previous studies of intentions in economic games, that is, that intentions play a greater role than consequences as a determinant of spiteful punishment. Rather, and in keeping with a growing body of psychological literature, they suggest a complex interaction of both factors in determining punishments and rewards, and a surprisingly large contribution of consequences. These results also introduce an important set of theoretical considerations: what are the functional roles of punishment and reward, and how these dictate people's reliance on intentional versus consequential information in social interactions?

Title: **Neural representation and behavioral impact of decision confidence**

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The explicit knowledge of one's subjective confidence or an estimate of uncertainty about one's beliefs can be advantageous for adaptive behavior, but it is controversial whether such knowledge arises from a "metacognitive" process unique to humans or a fundamental element of animal behavior. Moreover, little is known about where and how such higher-order knowledge is represented in the brain.

To investigate the neural bases of decision confidence, we used an integrated approach combining single neuron recordings, computational modeling and behavioral analysis. Rats were trained in an olfactory categorization task that allowed us to manipulate the uncertainty of discrimination problems by varying the distance of stimuli from the category boundary from trial to trial. We found that the activity of single neurons in the orbitofrontal cortex (OFC) reflected the probability of reward associated with stimuli of different difficulties, consistent with the known role of this area in representing reward value. In addition, OFC neurons also predicted the outcome (correct-rewarded/error-unrewarded) of individual decisions about stimuli of fixed difficulty. This pattern of results could not be explained by reinforcement learning models that update predictions based on past experience, but rather required computing an instantaneous measure of confidence in each choice along with the choice itself.

Next we sought to test whether rats are able to behaviorally make use of decision confidence to improve their chances of obtaining reward. Therefore, we modified the task by delaying reward delivery and allowing rats to abort and restart trials during the delay. We found that the pattern of trial restarts reflected the predictions of same model of decision confidence that also captured the neural data.

These findings strengthen the case that rats have "metacognitive" capacity to act on their degree of belief. Estimating decision confidence, however, may not necessitate higher-order processing: our model demonstrates that confidence can be mechanistically computed using elementary operations that are likely available to even simpler nervous systems. Together, these results indicate that a dynamic representation of and access to an explicit, internal measure of decision confidence is fundamental to adaptive behavior and provide insights into the nature of a core neural process underlying decision making.

Title: The effect of prior probability on decision making

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Most of the every-day decisions are made under uncertain circumstances where the exact probabilities are not known. Previous studies have suggested a number of brain regions that are related to the uncertainty in decision making. It has been proposed that dorsolateral prefrontal cortex, posterior parietal cortex, and frontomedian cortex are related to the decisions under uncertainty whereas the insular cortex activation is related to the uncertainty about future outcomes (Huettel et al. 2005). However, these studies do not address the question at which stage of the decision process the probability representations get integrated into the decision making process: Is the integration done purely at a high level evaluative phase? Or do the prior probabilities also have a top-down influence that tunes our perceptual system to pick up features of the expected stimuli category and thus bias our decisions towards the more probable option? As some recent studies suggest that perceptual areas that are related to recognition of face stimuli might receive predictive top-down feedback from frontal and parietal cortices (Summerfield et al. 2006), we designed a study to answer the questions above.

In the current fMRI paradigm we bias participants' perception of superimposed face and house images by introducing prior probabilities for the two image types. The task for the participants is to state whether the face or house features are more prominent in the images. To answer the questions stated above, we use a parametrical learning paradigm where three sequential mini-blocks are repeated: 1) biasing block with face and house images with a predefined ratio of faces/houses, 2) experimental block with superimposed face and house images for which the participants are at their indifference level, and 3) block with a baseline task. The number of face and house images in the biasing blocks is parametrically varied creating variable expectations for the stimuli types across the experimental run.

With the procedure, we are able to manipulate the ratio of face and house answers for the experimental stimuli for which participants should be at chance level for answering face or house. Furthermore, the reaction times are faster for the expected vs. non-expected stimuli. Additionally, the paradigm enables us to determine from the fMRI data whether there is anticipatory activity already in the perceptual regions such as the fusiform face area and the parahippocampal place area that reacts to the prior probabilities of the stimuli types.

Title: Social decisions & social norms: a neurobiological model.

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Abstract text (fill no more than this page)

Persuasion is a fundamental form of social influence on human decision making. While a focus of extensive psychological research, persuasion has been nearly ignored by cognitive neuroscientists. One of the most powerful techniques of persuasion is that of social norms effectively guiding our decisions, especially during times of uncertainty (Cialdini 2001).

Using functional magnetic resonance imaging (fMRI), we study the effects of social norms on attractiveness of faces. While scanning (N=24), we influenced females' judgments of female's attractiveness by normative ratings of faces (an average European rating). With our procedure, we introduced a conflict between subjects' own opinions and a group (normative) judgment. The normative ratings were false and systematically manipulated during the experiment according to participant's responses. Shortly after the fMRI session subjects rated again the same faces during a behavioral session. To identify the persuasive effects we compared brain responses to faces whose attractiveness was not changed with brain responses to faces whose attractiveness was effectively changed in accordance to the group (normative) opinion.

We found strong persuasive behavioral effects of group (normative) feedback on attractiveness of faces: perceived facial attractiveness significantly changed in accordance to the group (normative) opinion between the two sessions. fMRI data analysis revealed the brain areas activated by social conflict as well as the neural activity underlying persuasive effects of social norms. A relationship between conflict (error) detection, perceptual processing of faces, and future social decisions will be discussed.

Title: Self-Relevance Goal as Reference Point

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Abstract text (fill no more than this page)

One of the biggest problems facing traditional economic research is the phenomenon of mechanisms resulting from the subjective/objective distinction. Recent work in the field of neuroeconomics (Knutson & Peterson, 2005; Peoples, 2002; Damasio, 1999; Bechara & Damasio 2005) has shown an increasing understanding of subjective phenomena in decision-making. Subjectivity and objectivity are closely intertwined (Damasio 1999).

In our research project, the subjective/objective distinction in decision-making is described from the multidisciplinary viewpoints of Prospect Theory (Economic; Tversky & Kahneman, 1981), the Somatic Making Hypothesis (neuroscientific) (Bechara & Damasio, 2005; Damasio, 1994, 1999) and Autonoetic Mental Representation (psychological) (Geary, 2005; Tulving, 2002; Szpunar, Watson & McDermott, 2007). On the basis of these approaches, a neurophysiologically and behaviorally testable theory of decision-making will be presented to represent the elements of decision-making situations.

According to Prospect Theory (PT), people evaluate outcomes as gains or losses relative to a reference point (RP) (Tversky & Kahneman, 1981). It means that choices are not guided by the highest possible objective benefit, but rather by the most relevant and satisfactory subjective result, evaluated by personal experience (self-relevancy).

The Somatic Marker Hypothesis (SMH) (Damasio, 1994, 1999; Bechara & Damasio, 2005) is based on the argument that emotional signals assist humans during the decision-making process by rapidly highlighting options that have positive predicted outcomes and eliminating from further consideration options that have negative predicted outcomes. SMH showed that the ventromedial prefrontal cortex (VMPFC), amygdala and hippocampus are critically involved in the production of somatic markers. In this way decision-making is guided by emotional signaling generated in anticipation of future events.

According to the theory of Autonoetic Mental Representation (AMR), humans are unique in their capacity to formulate a representation of potential future states and to manipulate these images in ways that enable the simulation of control-related behavioral strategies (Geary, 2005). The future goals can help human to see long-term choices as more rewarding than short-term ones. The awareness of oneself as a continuous being through time and mental time travel are intimately linked on neurophysiological and cognitive levels (Geary, 2005). The value of a stimulus is evaluated in the dorsomedial prefrontal cortex (DMPFC). In the DMPFC, stimuli are processed on a self-nonsel self continuum. The DMPFC is critical when individuals represent their personal goals. (Lou, Luber, Crupain, Keenan, Nowak, Kjaer, Sackeim & Lisanby, 2004; Szpunar, Watson & McDermott, 2007). PT, SMH and AMR will be woven into a compact tapestry that constitutes a novel theory for empirically studying the neurophysiological basis of subjective decision-making. In the fall of 2007 the presented theory will be tested in a fMRI study.

Title: The Effect of Expectancy on Feedback-Related Negativity

Authors: Nai-Shing Yen^{1,2}, Ying-Ru Lai¹, Yin-Fang Chang¹, Tzu-Hsin Yeh¹, Kuan-Hua Chen¹

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Feedback-Related Negativity (FRN) is a frontal-distributed negativity, peaking approximately 250ms following feedback presentation, and larger after negative feedback. Previous studies suggest that FRN is sensitive to relative consequences rather than actual outcomes (e.g. Holroyd, Larsen, & Cohen, 2004). That is, a positive feedback worse than expected could elicit FRN, but a negative feedback better than expected might not elicit FRN. In present study, a reference point is provided to participants in a gambling task to examine the effect of expectancy on FRN. In the gambling task, participants select one of four decks each trial in order to obtain the maximum payoffs at the end of the game. Participants could win or lose 100, 200, 300, and 400 points in each trial. They were instructed that, on the average, the former participants could win 250 points in the winning trials and lose 250 points in the losing trials. According to the hypothesis that FRN is sensitive to the feedback worse than expected instead of the absolute outcome value, we predicted that FRN is larger when the outcome is worse than the expected +250 in the winning trials or - 250 in the losing trials. Nine undergraduates from National Chengchi University were recruited as participants. A 2 (actual outcome: win or loss) X 4 (amount: 100, 200, 300 or 400) X 3 (position: Fz, Cz, Pz) repeated-measures ANOVA were performed. The main effect of actual outcome was not observed, indicating that FRN is not sensitive to actual negative outcome. However, the interaction effect of actual outcome and amount was revealed. The pairwise comparisons indicate significant differences between win and loss in the amount of 100 and 400. A greater FRN was found after losing 400 (worse than expected) compared with winning 400 (better than expected). However, a greater FRN was found after winning 100 (worse than expected) instead of losing 100 (better than expected). Thus the "worse than expected" hypothesis is supported. Furthermore, a larger FRN occurred at Fz compared to the FRN at Pz, as suggested in previous findings.

Title: Deck C and D are preferred even when expected values in the Iowa Gambling Task are controlled

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A revised Iowa gambling task (IGT) was created in this study in which expected values (EV) of all the decks were adjusted to be equal. According to the somatic marker hypothesis (SMH), it was hypothesized that normal healthy participants might select equally across the decks. However, our data revealed that normal healthy participants ($n=16$) who received revised IGT showed similar selection pattern as whom received original IGT ($n=17$), that is, they both selected more A/B deck in the initial phase of the task, and then gradually switched to C/D deck when the task went on. Therefore, our data suggest that normal healthy participant prefer to deck C/D regardless its associated EV. Meanwhile, it is implied that there may be some other features, instead of EV, in deck C/D that attracts participants to select more C/D decks.

Title: **Is deck C an advantageous deck in the Iowa Gambling Task?**

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Background: Dunn et al. performed a critical review identifying some problems in the Somatic Marker Hypothesis (SMH). Most of the arguments presented by Dunn focused on the insufficiencies for replication of skin conductance responses and somatic brain loops, but the study did not carefully reassess the core-task of SMH. In a related study, Lin and Chiu et al. identified a serious problem, namely the “prominent deck B phenomenon” in the original IGT. Building on this observation, Lin and Chiu also posited that deck C rather than deck A was preferred by normal decision makers due to good gain-loss frequency rather than good final-outcome. To verify this hypothesis, a modified IGT was designed that possessed high contrast of gain-loss value in each trial, with the aim of achieving a balance between decks A and C in terms of gain-loss frequency. Based on the basic assumption of IGT, participants should prefer deck C to deck A based on consideration of final-outcome. In contrast, based on the prediction of gain-loss frequency, participants should have roughly equal preferences for decks A and C.

Methods: This investigation recruited 48 college students (24 males and 24 females) as participants. Two-stage IGT with high-contrast gain-loss value was launched to examine the deck C argument. Each participant completed the modified IGT twice and immediately afterwards was administered a questionnaire to assess their consciousness and final preferences following the game.

Results: The experimental results supported the predictions regarding gain-loss frequency participants choose the deck C with nearly identical frequency to deck A, despite deck C having a better final outcome than deck A. The “sunken deck C” phenomenon is clearly identified in this version of IGT which achieves a balance in gain-loss frequency. Moreover, the “sunken deck C” phenomenon not only appears during the first stage, but also during the second stage of IGT. In advance, questionnaires indicated that normal decision makers preferred deck C at neither the unawareness (implicit) nor consciousness (explicit) levels.

Conclusion: In the modified version of IGT, deck C was no longer preferred by normal decision makers, despite having a better long-term outcome than deck A. This study identified two problems in the original IGT. First, the gain-loss frequency between decks A and C is pseudo-balanced. Second, the covered phenomenon leads to most IGT related studies misinterpreting the effect of gain-loss frequency in situations involving long-term outcomes, and even leads to overstatement of the foresight of normal decision makers.

Title: Is deck E an advantageous deck in the inverted Iowa Gambling Task?

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Abstract text (fill no more than this page)

Bechara *et al.* developed the Iowa gambling task (IGT) to confirm the function of affective decision-making based on the performance difference between normal subjects and ventromedial prefrontal patients. In the original IGT, normal subjects preferred good final-outcome decks C and D and avoided bad final-outcome decks A and B. Additionally, the Iowa group created an inverted IGT generated from the original IGT with reversed signs (+ alter with -; - alter with +) in each trial (Brain, 2000). In the inverted IGT, decks E and G have positive final-outcomes (\$ +250) and decks F and H have negative final-outcomes (\$ -250). For an average of (first circle) 10 trials, deck E contained 9 losses and 1 gain (inverted B); deck G contained 5 losses and 5 gains (inverted A); deck F contained 7 losses, 1 draw and 2 gains (inverted C); deck H contained 9 losses and 1 gain (inverted D). Bechara *et al.* confirmed their hypothesis with the inverted IGT; in other words, normal subjects preferred to choose the good final-outcome decks (E+G) and avoided bad final-outcome decks (F+H). However, many IGT-related studies have suggested that the gain-loss probability as the guiding factor is more predictive than final outcome (Wilder *et al.*, 1998, Lin *et al.*, 2007). Consequently, in the inverted IGT, subjects should prefer decks G and F (few losses) rather than decks E and H (many losses). Unfortunately, the Iowa group subtracted the bad deck score from the good deck score to obtain an experimental result. The detailed number of cards selected for each deck cannot be fairly evaluated using their methodology. The inverted IGT was applied to verify the power of gain-loss frequency and final-outcome to guide choice. Moreover, a four-deck format is utilized in this study to clarify the argument between gain-loss frequency and final-outcome. In this experiment, 48 undergraduate students (24 males and 24 females) were recruited and gender effect was also controlled. This four-deck game was counterbalanced with 24 card positions (e.g. EFGH, EGHF, and EHFG). Participants performed the inverted IGT twice (two sessions) to identify their extended preference after the first session (100 trials). A questionnaire was administered following the game to assess player's final preference. The "sunken deck E" phenomenon was observed in this study. Deck E, which had a high loss frequency (good final outcome), was avoided by most subjects. This "sunken deck E" phenomenon is consistent with the gain-loss frequency identified by other studies, and inconsistent with the Iowa group's suggestion regarding final-outcome. Questionnaire results also identified the "sunken deck E" phenomenon on the explicit level of consciousness. Notably, the experimental results can also be congruent with the Iowa group's findings when the method of subtracting bad decks (F+H) from good decks (E+G) is utilized. Based on the Iowa group's suggestion (Brain, 2000), good final-outcome deck E should be preferred by most subjects in the inverted IGT. However, this study demonstrated that deck E was avoided by most normal subjects. This investigation demonstrated that the "sunken deck E" in the inverted IGT is similar to the "prominent deck B" phenomenon (Lin *et al.*, 2007) in the original IGT. If the "sunken deck E" is the case, the original interpretation of the IGT should be considered an alternative gain-loss frequency explaining decision behavior under uncertainty.

Title: Gender difference of sensitivity for gain-loss frequency in the Soochow gambling task

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Web address URL for a paper (if available):

Abstract text (fill no more than this page)

Background: Bolla *et al.* (Cerebral Cortex, 2004) utilized the Iowa gambling task (IGT) and brain imaging (PET) technique to explore gender difference. They observed that males performed better than females on behavioral level and determined that gender difference was observed on brain level. Based on findings obtained by IGT-related studies, males are more sensitive than females to final outcome under uncertainty. Over past two years, the Soochow gambling task (SGT) has demonstrated that normal decision makers are insensitive to final outcome in serial uncertain gambling. The Soochow group determined that gain-loss frequency may be more dominant than final outcome in guiding choice under uncertainty. However, no direct evidence exists for gendered difference in the SGT. In fact, decks A and B have bad final outcome (\$ -250 over an average of 5 trials) and decks C and D have good final-outcome (\$ +250 over an average of 5 trials) in the SGT. Furthermore, decks A and B contained high-frequency gains (4 gains and 1 loss), whereas decks C and D contained high-frequency losses (4 losses and 1 gain). First, this experiment will provide further data regarding the weighting between gain-loss frequency and final outcome in guiding decisions in the real-money gamble. Second, gender difference will be evaluated for gain-loss frequency and final outcome outcome levels.

Methods: This study enrolled 48 participants (24 males and 24 females) who performed the computer version of the SGT. These subjects are all graduates of college or high school. At the start of the game, each subject was informed that they will gain the real money (NT\$ 0-500) based on their final outcome in this game. Following this game, subjects were required to answer a questionnaire used to identify their final preference on a conscious level.

Results: This study replicated the original finding of the SGT that normal decision makers preferred to choose the high-frequency gain decks A and B which have bad outcomes. Notably, normal decision-makers are insensitive to the final-outcome in the SGT. Moreover, females have a greater tendency than males to choose high-frequency gain decks. Restated, high-frequency loss is more tolerable for males than females. However, this gender difference is not statistically significant. Questionnaire results determined that subject preference was guided most by gain-loss frequency and not final outcome. Females were more sensitive to gain-loss frequency than males on the explicit level of consciousness.

Conclusion: This real-money experiment identified a little gendered difference in the SGT, indicating that most subjects are unable to foresee final outcome. In the SGT, decision-making behavior is highly correlated to gain-loss frequency. Additionally, females are perceptive of gain-loss frequency than males. Regardless of whether on an implicit or explicit level, a little gendered difference in sensitivity for gain-loss frequency can be observed under uncertainty.

Title: Is decision-maker sensitive to expected value in the dynamic-uncertain gambles?

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Abstract text (fill no more than this page)

Background: Behavioral decision literature suggests that decision makers are less guided by expected value (EV). However, the performance of a dynamic and uncertain gambling task, the Iowa gambling task (IGT), concludes with a very different implication regarding expected value. Notably though, a similar and simpler game, the Soochow Gambling Task (SGT) showed that gain-loss frequency rather than final-outcome (EV) exerted a more powerful guiding effect on dynamic decision-making. The exact influence of EV in guiding decision makers is still demanding further clarification. The present experiment provided two modified SGT to explore the EV effect under the same gain-loss frequency context as original SGT. In the modified SGT, decks A and B have high-frequency gain (4 gains and 1 loss) and decks C and D have high-frequency loss (4 losses and 1 gain). In the high-frequency gain context, deck A has a **negative** final-outcome (-250), deck B a **positive** final-outcome (+250); in the high-frequency loss context, deck C has a **positive** final-outcome (+250), deck D a **negative** final-outcome (-250). If final-outcome (EV) should have any effect on guiding decision-making, deck B ought to be preferred than A in the high-frequency gain context; deck C ought to be preferred than D in the high-frequency loss context. On the contrary, if final-outcome has no effect on choice behavior, decks A and B should be equally preferred; decks C and D should also be identically chosen.

Methods: The modified SGT was conducted by 24 undergraduate students at Soochow University. Each subject performed one set of card position (e.g. ABCD, BCDA, CDAB and so on) to prevent the position effect. A computer version of SGT was presented with Matlab 6.5 programming and participants' choices were recorded and analyzed. Following the game, subjects were required to memorize their choice pattern for identifying their preference in the modified SGT.

Results: Both versions of SGT consistently demonstrated that high-frequency gain decks A and B were most favored by the participants. Subjects preferred the bad final-outcome deck A equally with good final-outcome B. Subjects also chose among the bad final-outcome deck D and the good final-outcome C almost identically. The learning curve result demonstrated that the final-outcome had little power to influence the choices from the beginning to the end of the game. Additionally, subjects' recollections in questionnaire were also congruent with their choice patterns.

Conclusion: According to the original assumption of IGT, decision makers should be sensitive to the EV in these dynamic-uncertain gambles, but this assertion contradicts with the present finding. The experimental results demonstrates that the final-outcome (EV) does not significantly influence decision makers under either the frequent-gain or frequent-loss context. Most decision makers were guided by the gain-loss frequency and were little influenced by the manipulation of final-outcome.

Title: Growing evidence of prominent deck B phenomenon in Iowa Gambling Task

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Web address URL for a paper (if available):

Abstract text (fill no more than this page)

The “prominent deck B phenomenon” of Iowa gambling task (IGT) has been demonstrated by Lin, Chiu, Lee, and Hsieh (2007) with a simple version of IGT. In Lin et al. experiment, bad (final-outcome) deck B was almost equally preferred to good (final-outcome) deck D by normal decision makers. This phenomenon is a violation of the basic assumption of IGT. However, the original IGT has been conducted in excess of hundred scientific, neurological and psychiatric studies over the past years and only a few studies had observed the “prominent deck B” phenomenon, as in Wilder et al. (1998), MacPherson et al. (2002) and Caroselli et al. (2007). To clarify this issue, a meta-analysis was conducted to investigate the “prominent deck B phenomenon” among normal decision makers based on two lines of literature pools: (1) Iowa group’s data with the original IGT from 1994 to 2007; (2) the other research groups’ results which also adopted the original IGT. Most papers were collected from the search engine on internet and library data base, for example: Google Scholar, Medline and so on. Part of the papers were collected from Dunn et al. (2006) review. The result indicated that most IGT related studies adopted the “two-category” format (bad [A+B] vs. good [C+D]) to present their data, therefore the single selection frequency of deck B can not be singled out. The “two-category” format prevailed in most Iowa group’s findings, except the studies published on Cognition (Bechara et al. 1994) and Schizophrenia Research (Sevy et al. 2007). In these two studies, the Iowa group adopted the “four-deck” format (A, B, C, D) to present the IGT data. The Iowa group’s study in 2007 showed the “prominent deck B” phenomenon, healthy subjects preferred the bad deck B to the other three decks. The selection frequency of deck B (31 trials) in 2007 is almost double that of deck B (17 trials, observed from the figure) in 1994. Additionally, this review found that eleven other studies presented their data with “four-deck” format and nine out of eleven studies demonstrated a “prominent deck B” phenomenon, including the Wilder et al. (1998), O’Carroll et al. (2003), Crone et al. (2004), Ritter et al. (2004), Bark et al. (2005), Rodriguez-Sanchez et al. (2005), Toplak et al. (2005), Caroselli et al. (2006), and Fernie et al. (2006) studies. That is, most studies with four-deck format presentation revealed a “prominent deck B” phenomenon. In this review, we found that most of Iowa group’s studies adopted the “two-category” format to present their data and with an exception of two studies that provided the “four-deck” format. Therefore, the “prominent deck B” phenomenon can not be easily clarified through this line of studies. Nevertheless, the 2007 study of Iowa group showed a “prominent deck B” phenomenon. On the other hand, this review found that although most other groups also followed a “two-category” format, there were eleven studies that adopted the “four-deck” format. Most of these eleven studies showed a “prominent deck B” phenomenon. Based on the present survey, “prominent deck B” phenomenon should not be construed as an isolated finding. The growing evidence concerning with a prominent deck B preference in the IGT thus deserves further clarification in the future studies.

Title: **Is deck B an disadvantageous deck in the Iowa Gambling Task?**

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Web address URL for a paper (if available): <http://www.behavioralandbrainfunctions.com/content/3/1/16>

Abstract text (fill no more than this page)

Background: The Iowa gambling task is a popular test for examining monetary decision behavior under uncertainty. According to Dunn et al. review article, the difficult-to-explain phenomenon of “prominent deck B” was revealed, namely that normal decision makers prefer bad final-outcome deck B to good final-outcome decks C or D. This phenomenon was demonstrated especially clearly by Wilder et al. and Toplak et al. The “prominent deck B” phenomenon is inconsistent with the basic assumption in the IGT; however, most IGT-related studies utilized the “summation” of bad decks A and B when presenting their data, thereby avoiding the problems associated with deck B.

Methods: To verify the “prominent deck B” phenomenon, this study launched a two-stage simple version IGT, namely, an AACC and BBDD version, which possesses a balanced gain-loss structure between advantageous and disadvantageous decks and facilitates monitoring of participant preferences after the first 100 trials.

Results: The experimental results suggested that the “prominent deck B” phenomenon exists in the IGT. Moreover, participants cannot suppress their preference for deck B under the uncertain condition, even during the second stage of the game. Although this result is incongruent with the basic assumption in IGT, an increasing number of studies are finding similar results. The results of the AACC and BBDD versions can be congruent with the decision literatures in terms of gain-loss frequency.

Conclusion: Based on the experimental findings, participants can apply the “gain-stay, loss-shift” strategy to overcome situations involving uncertainty. This investigation found that the largest loss in the IGT did not inspire decision makers to avoid choosing bad deck B.

Title: Regulatory Fit Effects in a Gambling Task

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Abstract text (fill no more than this page)

We examined the interface between motivation and choice. In category learning, a regulatory fit has been shown to increase exploration of alternative response strategies even when exploration is sub-optimal. In the current study, promotion and prevention focus subjects performed a gambling task that required them to choose from one of two decks on each trial. They either gained or lost points with each draw. In Experiment 1, optimal performance required an exploratory response pattern that entailed sampling from a deck that initially appeared disadvantageous but ultimately became advantageous. In Experiment 2, optimal performance required an exploitative response pattern. A softmax reinforcement learning model that includes an exploitation parameter was applied to the data and revealed greater exploration of alternative strategies for people with a regulatory fit. This response strategy was optimal in Experiment 1 and led to superior performance, but was sub-optimal in Experiment 2 and led to inferior performance.

Title: Brands as social tools: an fMRI study differentiating implicit and explicit commercial brands impressions.

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Institution: (1) Investigation Unit in Human Development and Psychology (Unidep), ISMAI - Superior Institute of Maia, Portugal; (2) Applied Economy Department, Economy Faculty, Coruña University, A Coruña, Spain; (3) Radiology Department, MRI Unit, São João Hospital, Oporto, Portugal; (4) Institute of Histology and Embryology, Faculty of Medicine, Oporto University, Portugal; (5) Neuroradiology Department of São João Hospital,

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Abstract text (fill no more than this page)

Introduction: A few studies have been reporting the neurological underpinnings of impression formation. Common to some fMRI experiments, are the instructions that volunteers receive to explicitly form an impression, normally between people and objects. But, is this how people form impressions of others or objects? Practice shows that individuals form impressions of their peers implicitly, and implicitly use this information when making social trades with them.

Objectives: It remains uncertain the neural circuitry engaged in commercial brand processing, and whether distinct systems are involved when compared to impression formation of faces or objects. Our objective was to investigate these issues, pertaining in particular frontal, temporal and limbic areas, also attempting to determinate if explicit or implicit processing of commercial brands is in fact different.

Methodology: To explore these issues, we designed a functional magnetic resonance imaging (fMRI) task, made-up by two paradigms (runs), that encompasses commercial brands as stimulus. In the first run volunteers were only instructed to look at the screen during the scanning; nothing was said about what they are about to see. Then, in the explicit run, we instructed the volunteers to make mental assessments of the brands they would see. The order of the runs was crucial: being first the implicit task, we expected to capture the volunteers free willing and avoid any anticipation. Data was processed using FMRIB Software Library (FSL), release 3.3.

Results: Results were divided in three groups: brain activations that were common to both runs and those that occurred either in the implicit run or in the explicit run. In the frontal lobe we registered several areas with activations on both runs, implicit and explicit: inferior frontal gyrus (Broca's area), dorsolateral and ventromedial prefrontal cortex, and frontopolar and supplementary motor areas. In the temporal lobe common activations occurred in the middle, inferior, angular, parahippocampal and fusiform gyri and amygdala. Activations in the insula, anterior cingulate and Wernicke's area were also found on both runs. Exclusive to the implicit run were activations in the temporal pole, hippocampus and precuneus. Exclusive to the explicit run were activations obtained in the putamen, thalamus and premotor area. Generally, the most ventral areas of the prefrontal cortex and the temporal lobe were more active in the implicit run. The most dorsal areas of the prefrontal cortex and the motor areas were more active in the explicit run.

Conclusions: Commercial brand processing involves complex neural circuitry, and instructing or not instructing individuals about them, can influence the brain areas enrolled. Common activations in areas such as the prefrontal cortex, responsible for brain functions such as working memory, decision making and reward, confirm the similar nature of both tasks, implicit and explicit. Both tasks also revealed activations of the limbic system and paralimbic areas, albeit more extensive in the implicit task. We hypothesize that the limbic system is involved due to the emotional content that each stimulus - commercial brand - holds. Together with the extensive and intensive involvement of the temporal lobe (mainly in the implicit run), which correlates with the "social brain", we speculate that the stimulus used has also a strong social content: brands as social tools.

Title: Orbitofrontal cortex encodes willingness to pay in everyday economic transactions

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Web address URL for a paper (if available): will be happy to email on request (paper is under review)

Abstract text (fill no more than this page)

An essential component of every economic transaction is a willingness-to-pay (WTP) computation in which buyers calculate the maximum amount of financial resources that they are willing to give up in exchange for the object being sold. Despite its pervasiveness, little is known about how the brain makes this computation. We investigated the neural basis of the WTP computation by scanning hungry subjects' brains using fMRI while they placed real bids for the right to eat different foods. We found that activity in the medial orbitofrontal cortex and in the dorsolateral prefrontal cortex encodes subjects' WTP for the items. Our results support the hypothesis that the medial orbitofrontal cortex encodes the value of goals in decision-making.

Title: Social influences on bidding in common value auctions and the Winner's Curse

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Abstract text (fill no more than this page)

When bidding for items of fixed, but uncertain value, people consistently fail to adequately use the information available to them. In particular, participants bid consistently higher than is predicted from rational models. The consequence of this inflated bidding is the Winner's Curse: auction winners frequently lose money on auctions or at least do not earn as much as is possible (Capen et al., 1971).

Avoiding the Winner's Curse requires modifying bids conditional on the possibility of winning the auction. This results from the fact that larger bids have both a higher probability of winning in a first price auction and also a higher probability of being greater than the true value of the good. The dominant explanation for the Winner's Curse supposes that people have insufficient cognitive abilities and hence are unable to overcome the curse (Eyster and Rabin, 2005).

We demonstrate that the Winner's Curse is not simply a consequence of limited cognitive capacity. Experienced auction participants were instructed how to perform in accord with rational models. Under this condition, the Winner's Curse persists. Meanwhile, when separate sets of subjects are instead entered into auctions with computer opponents, the curse is significantly smaller both when (i) the computers play according to rational models, and (ii) when the computers match human bidding behavior. These results demonstrate that the Winner's Curse is not strictly the result of cognitive limitations since subject can perform rationally when properly instructed about the strategies and play against non-human components. Instead, overbidding in common value auctions results when auctions involve human competitors suggesting that social motivations such as concern for social hierarchy might play an important role in auction behavior, which would have further implication in future auction designs.

The future directions of this project is investigating the neural mechanisms of decision-making in auctions in a hyper-scan experiment. Contrasting the activity of experienced participants in real auctions with those in auctions with computer players may provide insight on how the social factors influence decision making.

Title: **The Neurobiological Effect of Social Information on Preferences and Risk Attitudes in the Adolescent Brain**

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Web address URL for a paper (if available):

Abstract text (fill no more than this page)

Purpose: We present the results of two experiments with adolescent subjects. The first experiment correlated behavior and neural activity during risky decision making with real-world dangerous behavior. The second experiment was designed to investigate how a simple message, like popularity, changes an individual's attitude toward risk and what the potential neural basis of such a change might be.

Methods: In Experiment 1, we used the adolescent risk questionnaire (ARQ) as a proxy for real-world risk-taking behavior and coupled this instrument with a simple imaging probe of decision making under risk. In the scanner, subjects were presented with a "roulette task." Subjects had to pick the color they thought a ball would land on. If they guessed correctly, they received a squirt of their favorite drink from several that they sampled earlier. If they guessed incorrectly, they received a small squirt of their least favorite drink. Four probability levels of winning were used ($1/2$, $5/8$, $3/4$, and $7/8$). Outside the scanner, we also used a probe of financial risk-attitude that has been validated in adolescents (Harbaugh et al., 2002).

In Experiment 2, we modified the Harbaugh task to include a Social Information Treatment. After each individual made his decisions on the lotteries, they repeated the decision-making process with the most popular choice (from Expt 1) indicated on each lottery. The scanning phase examined the effect of popularity rankings on both preferences and neural responses to music. Participants listened to 15-second music clips and rated how much they liked the song played in the clip. At the end of the session they received a CD with their 10 most highly rated songs. Each song was played twice, and the participant had the opportunity to revise her ranking after the second playing. On half of the trials, a popularity ranking, computed from the number of downloads on MySpace, was shown during the playing of the song.

Results: After adjusting for age and IQ, there was a significant correlation between the neural response to probability on the roulette task and the subjectwise ARQ in Experiment 1 ($N=20$). High risk takers had greater activation in a fronto-parietal network to low probability roulette wheels, whereas low risk takers had greater response to high probability wheels.

In Experiment 2, we found a significant effect of popularity on financial risk attitude ($N=21$). When the popular choices were revealed, we observed a significant increase in gambling behavior. There was a non-significant trend for "safe" behavior when these were the popular choices. Thus, the social norms changed individual risk attitudes in a direction consistent with the norm, but a stronger tendency for popular risky choices to change behavior more than safe ones. A similar pattern was found for ratings on the music task. When participants changed their ratings between the 1st and 2nd listenings, they did so in the direction of popularity 80% of the time. The brain imaging results for the music showed that the 2nd listening of each song was associated with less activity than the first in all regions that responded to the music. However, when the popularity was shown simultaneously, *activity in the ventral striatum decreased significantly more*.

Conclusions: Adolescents who score high on real-world risk-taking show increased frontoparietal activity toward risky lotteries as if they pay more attention to the risk than the outcome. Adolescents who with low real-world risk-taking devote more attention to lotteries with a high likelihood of a positive outcome; i.e. "bad kids" focus on risk, while "good kids" focus on outcomes. However, preferences for music and for financial risk-taking can be modulated in the laboratory by simple messages that indicate popularity.

Title: The origins of trust

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Abstract text (fill no more than this page)

Introduction: Trust is an important element of a flourishing economy and a cooperative, stable society (e.g. Axelrod, 1984). Hence it does not surprise that trust has also become a core concept in modern economic research, which has already developed models to explain the existence and mechanisms of trust. However, most of these models are still built on the assumption of rational decision making (Coleman, 1990), although recent findings - emphasizing the influence of unconscious emotional factors (Dijksterhuis et al. 2006) - clearly contradict this 'classical' assumption. Hypothesizing that such emotional factors are also essential for developing trust, we conducted an fMRI-Experiment during a modified dictator game, expecting to find activation differences in emotion processing brain regions (Delgado et al. 2005).

Methods: Twelve healthy subjects, randomly selected from people reacting on a newspaper announcement, participated in the experiment (9 w, 3 m, age: 41 - 16 years (mean SD)). A dictator game was modified according to King-Casas et al. (2005) to a multi-round format, where the player (P) had to play 20 rounds each with four dictators ("D_A", "D_B", "D_C", "D_D"), who were initially unknown to the participants, in a pseudo-randomized order. Every round P had a small amount of money (2 €), which could be shared, kept or completely given to the dictators. The behavior of the dictators was predefined but initially not known for P: while P regularly received 1 or 2 € from the dictators D_C and D_D, who are called 'benevolent' in the following, the 'malevolent' dictators D_A and D_B regularly took 2 or 1 € from P, so that the total money flow was D_A: 20 €, D_B: 10 €, D_C: 10 €, D_D: 20 €. During the fMRI-experiment portraits of the dictators and the amounts given or taken were displayed on a screen inside the tomograph and P indicated his/her choice by pressing a button on a response box. On the behavioral level trustworthiness of the dictators was assessed before and after the fMRI-experiment according to Bierhoff and Buck (1984). Functional MRI data were analyzed with SPM2.

Results and Discussion: After the game trustworthiness had significantly increased for D_D (most benevolent), decreased for D_A (most malevolent), whereas trustworthiness of D_B and D_C remained unchanged. An initial fMRI analysis showed that compared to D_A the presence of D_D induced significant higher activations in the ventromedial prefrontal cortex (VMPFC), the ventral tegmental area and the basal ganglia. These brain areas, especially the VMPFC, are known to be essential for the integration of emotions into decision-making (Bechara et al, 1997, Deppe 2005a, Deppe2005b), or to be activated by (monetary) rewards (O'Doherty 2001) as part of the mesolimbic reward system. Thus, we conclude that trust-building between initially foreign subjects appears to be strongly influenced by emotions, which are often neglected in economic theory.

References are not included due to space limitation but will be provided on demand.

Title: **Monetary sacrifice among strangers is mediated by endogenous oxytocin release after physical contact**

Authors: Vera B. Morhenn, Jang Woo Park, Elisabeth Piper and Paul J. Zak

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Abstract text (fill no more than this page)

Humans frequently sacrifice resources to help others--even strangers. The proximate mechanisms inducing such sacrifices are not well understood, and we hypothesized that touch might provoke a sacrifice of money to a stranger. We found that touch significantly elevated circulating oxytocin levels but only when it was followed by an intentional act of trust. Touch followed by trust increased monetary sacrifice by 243% relative to untouched controls. We also found that women were more susceptible than men to OT release and monetary sacrifice after touch. This suggests that touch draws on physiologic mechanisms that support cooperative behaviors in humans.

| Poster Session II, Friday 1:45 pm – 3:45 pm | |
|---|--|
| Authors | Title |
| Andrew Caplin, Mark Dean, Paul W. Glimcher, Robb Rutledge | Dopamine and reward prediction error: Theory and evidence |
| Eric E. J. DeWitt, Mark Dean, Paul W. Glimcher | Learning in uncertain environments: Measuring human performance against a normative benchmark |
| Robb B. Rutledge, Brian Lau, Stephanie C. Lazzaro, Catherine E. Myers, Mark A Gluck, Paul W. Glimcher | Parkinson's disease and dopaminergic drugs modulate human reinforcement learning rates |
| Amy L. Krain, Kristin Gotimer, Ifat Levy, Paul W. Glimcher | Measuring aversion to risk and ambiguity in children and adolescents |
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| Joseph W. Kable, Paul W. Glimcher | Constraining the neural algorithm for intertemporal choice |
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Title: Dopamine and Reward Prediction Error: Theory and Evidence

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Abstract text (fill no more than this page)

Neurobiological studies over the past 50 years show that dopamine plays a role in economic decision-making. While many scholars now believe that the activity of dopamine neurons encodes the difference between experienced and predicted reward, a reward prediction error (RPE), there are other possibilities that have not been unambiguously excluded. These include the incentive salience hypothesis of Berridge and Robinson (1998), the attention switching model of Redgrave and Gurney (2006) and the salience hypothesis of Zink et al. (2003). Indeed, it has not been unambiguously demonstrated that the activity of midbrain dopamine neurons has all of the properties of a reward prediction error system. This stems from the fact that no theorist has ever specified a complete list of the properties an RPE encoder would have to show, and that no experimentalist has ever attempted to demonstrate that dopaminergic activity has these properties.

We therefore used the standard tools of economic theory to derive an axiomatic basis for the RPE hypothesis. These compact mathematical axioms describe the properties that any system would have to obey if it were to serve as an RPE encoder. They serve as a complete and formal description of what it would mean to be an RPE system. Our approach also allows us to nest RPE models of increasing complexity. Our main result captures a 'minimalist' notion of an RPE system, defining the concept of experienced and predicted reward such that output is increasing in the former and decreasing in the latter. Subsequent axioms impose more structure on an RPE system, describing how more advanced encoding systems would have to behave. This approach allows us to define formally the role of the unobservable (used here in the technical economic sense) variable 'reward' with respect to observable variables such as dopamine activity and choice in a complete and rigorously testable manner. In contrast, more traditional neuroscientific approaches (e.g. Bayer and Glimcher, 2005) fit examples of RPE models to neural data and assess the fit of that particular model as a test of the hypothesis that dopamine encodes RPE. The axiomatic approach specifies precisely the properties of the spike train which are both necessary and sufficient for concluding that the neurons can serve as an RPE system.

Finally, we present fMRI data that explicitly tests our axioms and therefore the RPE theory. We consider the simplest possible environment in which 'reward prediction' makes sense - one in which subjects receive monetary prizes from different lotteries. By scanning subjects as they are informed of what prize they have won from a lottery, we can test whether brain areas can be modeled as responding to the difference between the 'predicted reward' of the lottery and the 'experienced reward' of the obtained prize. A typical trial begins with the presentation of two lotteries in pie-chart form on a screen. The subject chooses between these two lotteries, with the chosen lottery moving to the middle of the screen. After a delay, the outcome of the lottery is realized, and the resulting prize is highlighted to the subject. At this point, we collect data from known dopamine output areas - the nucleus accumbens, putamen, medial prefrontal cortex defined using both anatomical and functional techniques. By comparing these data to our axioms, we can determine not only whether or not activity in a particular area satisfies the RPE model, but also the nature of any departure from that model.

Title: Learning in uncertain environments: measuring human performance against a normative benchmark.

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How we learn the expected value of an action is a fundamental question for microeconomic theory but one that has been difficult to study in a normative context. Prior behavioral economic research in restricted learning environments (e.g. repeated games) has not been able to leverage the extensive behavioral—and recent neurobiological—research on learning from the outcome of one's actions. In contrast, prior neuro-psychological studies of reinforcement learning in humans have used tasks that precluded comparison to an known optimal behavior. Without an optimal benchmark, it is impossible to assess whether changes in learning behavior are appropriate for changes in the environment and how observed behavior differs from the optimal behavior. It is also impossible to relate any observed inefficiencies in behavior to inefficiencies in neural activity. Our goal was unite the normative approach from economics with neural and psychological studies of mechanism to better understand learning. To that end we have developed a task that can present a wide range of dynamic learning environments with a known optimal policy for learning that is broadly similar to classic tasks for studying learning. This task allows us to relate observed choice behavior to the putative underlying neural mechanisms which may provide novel predictions about choice not available from the observed behavior alone.

We used our task to compare human choice behavior to that of an ideal decision maker in a variety of environments that call for different learning rates. Our task, an n-armed drifting bandit, allows us to select task parameters that specify any optimal learning rate we desire. A Gittins' index solution based on this optimal rate can be used to specify the best action on a choice-by-choice basis. In the task subjects face two 'arms' that each return random rewards, the magnitude of which is drawn from Gaussian distribution. When an arm is sampled, the mean of this distribution drifts unpredictably (also drawn from a Gaussian). The functional form of the recursive optimal solution to such a bandit is identical to classical models of reinforcement learning. We can thus independently specify two parameters that define the optimal learning rate: the variability in reward magnitude and the drift rate. Importantly, these two parameters trade-off. Increasing drift rate and increased variance can cancel to yield a constant optimal learning rate.

Using this task we tested two hypotheses in humans. 1) Do subjects adjust their learning rate when the optimal rate changes. We found that while humans employ a learning rate that is too high (recent reinforcements are over-weighted), they do so in a consistent manner. When changes in the environment call for higher or lower learning rates, humans do significantly increase or decrease their learning rates, maintaining a roughly constant level of learning efficiency. 2) Do subjects correctly trade-off the different sources of reward variation we impose? We found that they do, correctly integrating these two influences when adjusting their learning rate.

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Title: Parkinson's disease and dopaminergic drugs modulate human reinforcement learning rates

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A recent study has examined human choice behavior in the concurrent variable interval (CVI) environment widely used to study animal decision-making (Rustichini et al., 2005). In that experiment, subjects chose between two options. Rewards were scheduled with different independent rates and scheduled rewards remained available until the associated option was chosen, in accord with standard CVI processes. Reinforcement learning models accurately predict choice behavior in monkeys under these conditions (Sugrue et al., 2004; Lau & Glimcher, 2005). We developed a method to rapidly assess reinforcement learning in human subjects in a very similar task (after Lau & Glimcher, 2005). On each trial, subjects choose one of two animated crab traps. Rewards (crabs worth \$0.10) were scheduled with different independent rates and remained available until the associated target was chosen, as in the CVI environment. After a 5-minute training period, subjects completed 800 trials as we varied reward probabilities across 10 blocks of 70-90 trials. Under these conditions, we found that reinforcement learning models accurately predicted both steady-state and trial-by-trial choice dynamics in humans as they do for monkeys.

The midbrain dopamine neurons are thought to encode the reward prediction error signal required by reinforcement learning models (Schultz et al., 1997; Bayer & Glimcher, 2005). Therefore, manipulations that modulate the activity of the dopamine neurons should affect how subjects learn about and value options, and should consequently affect choice behavior. The learning rate parameter in reinforcement learning models should capture this variation. Parkinson's disease (PD) is characterized by a loss of midbrain dopamine neurons. Dopaminergic drugs including the dopamine precursor L-Dopa and dopamine receptor agonists are taken to relieve disease symptoms. We hypothesized that patients with moderate PD show atypical reinforcement learning and choice behavior off dopaminergic medication due to dopamine neuron loss, and show more normal reinforcement learning and choice behavior on dopaminergic medication. PD patients (n=19) completed one session on and one off dopaminergic medication. PD patients were highly educated (average education = 17.0 years) and otherwise healthy. Age-matched controls (n=21) and healthy young subjects (n=20) completed one session. We found that young and elderly control subjects had similar reinforcement learning rates, but learning rates were reduced in PD patients tested off medication. When those same PD patients were tested on medication, learning rates were restored to control levels. These data provide causal evidence supporting a role for dopamine in human reinforcement learning and suggest that modulating dopamine activity modulates valuation processes and thereby influences decision-making.

Title: Measuring Aversion to Risk and Ambiguity in Children and Adolescents

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While prospect theory and its components have been studied extensively in adults, few studies have examined how decision-making under risk develops during childhood and adolescence. There is some evidence that children make more risky decisions than adults (Levin & Hart, 2003). This may reflect a tendency to “underweight” low probability events, particularly negative events (Harbaugh et al., 2002). Further, recent neurocognitive models suggest that the maturation of prefrontal cortex that occurs during adolescence leads to an imbalance in the reward (ventral striatum) and avoidance (amygdala) systems resulting in more risky behavior (Ernst et al., 2005). Despite this evidence for developmental changes in risky decision-making, no studies have examined the components that make up this behavior. The current study uses an adaptation of the Ellsberg paradigm to evaluate risk and ambiguity aversion in children and adolescents (ages 8- 17). Evidence suggests that traits, such as shyness, in children are associated with decreased risk taking. Therefore, we are also examining anxiety and intolerance of uncertainty to determine if any specific traits, particularly those associated with the development of anxiety disorders, are associated with risk and/or ambiguity aversion. Methods: Forty children are currently being recruited. Participants complete a diagnostic interview as well as measures of intellectual functioning, anxiety, worry, indecisiveness, and intolerance of uncertainty. The decision-making task, designed by Dr. Ifat Levy at the NYU Center for Neural Science, asks participants to choose between two lotteries involving bags filled with red and blue poker chips. In one of the lotteries, the number of red and blue chips varies. Each color is associated with a number indicating the number of *francs* (imaginary currency) that the participant would win if that lottery was played and that color was selected. Participants choose whether they prefer to play the lottery they are shown or a reference lottery in which there is a 50% chance of winning 50 francs. In some trials, part of the lottery is occluded, preventing the participant from knowing exactly what the distribution of red and blue chips is. After the participant completes the task, three trials are selected at random. The child is asked to draw a chip from the bag that was chosen in that trial and is paid according to this draw at the exchange rate of 1 dollar for 10 francs. Results: Preliminary data suggest that adolescents are playing the game lawfully, choosing the varied option more often for higher rewards, higher probabilities, and lower ambiguity levels. However, compared to adults, their choices are less consistent and demonstrate more risk aversion. This latter result is surprising given the evidence for increases in risky behavior during this developmental period. Data collection is ongoing. Implications: Understanding developmental changes in risk and ambiguity aversion can provide us with a more comprehensive understanding of child and adolescent decision-making. Given the number of adolescent psychiatric conditions associated with decision-making deficits (i.e., ADHD, anxiety disorders, substance use), we hope to gain insight into the specific mechanisms underlying these deficits with the ultimate aim of examining their neural correlates.

Title: The effect of non-chosen choices: relative reward coding in parietal area LIP

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Under rational choice theory, a decision-maker with well-ordered preferences is always better off with more options from which to choose. However, a growing body of economic and psychological research suggests that more options can be detrimental to human decision-makers, leading to choices with worse perceived outcomes. These results have been hypothesized to arise from cognitive limitations such as incomplete information processing or the cost of increased cognitive effort with large choice sets, but to date the neural basis for the effect of increased options on choice behavior remains unknown.

We examine this issue in the context of reward and value coding during decision-making processes. Reward information is a critical element of optimal choice behavior. Recent evidence suggests that many of the neural systems underlying decision-making encode the reward contingencies of available actions. In the monkey lateral intraparietal area (LIP), visuomotor neurons are strongly modulated by reward-related variables such as the expected gain and prior probability of reinforcement, which control the value of the associated saccades, suggesting that a neural representation of value is an integral part of the decision mechanism. More recently it has become clear that this neural representation takes the form of subjective encoding; firing rates are linear functions of subjective, rather than objective, measures of value.

While it is now clear that the subjective value of actions is represented in decision-making circuits, the exact form of that representation remains uncertain. Each LIP neuron may encode the subjective value of its associated saccade, independent of other available rewards and actions. Alternatively, the subjective value of a given saccade may be represented in a relative form, for example normalized against all other available rewards (as in a gain ratio): $V1 = V1 / \text{SUM}(V_{\text{all}})$. One advantage of such a relative representation is that it can achieve dynamic range compression and optimal efficient coding, both properties that have been well studied in visuo-cortical circuits.

To determine if LIP neurons encode subjective value in an absolute or relative manner, we examined the activity of single LIP neurons while varying the reward for movements that lay outside the response field of the LIP neuron under study. For each neuron, two targets were presented during central fixation, one inside the response field (IN target) and one well outside the response field (OUT target), typically in the opposite hemifield. Monkeys subsequently were instructed on different trials to choose the IN target or the OUT target, or were free to choose either target. In contrast to previous studies, we manipulated the magnitude of the OUT target reward, holding the reward associated with a saccade to the IN target constant, as well as manipulating the IN target reward while holding the OUT target reward constant.

We find that LIP neurons are strongly and negatively correlated with the magnitude of reward associated with the OUT target and positively correlated with the reward associated with the IN target. Furthermore, we show that this negative relationship between LIP activity and OUT target reward is entirely consistent with the positive correlation between LIP activity and IN target reward, if subjective values are expressed in terms of a gain ratio. These results show that the neural representation of the value of options is affected by the other available option; this dependence of option value on choice set may provide a mechanistic insight into human deviations from rational choice theory.

Title: Constraining the neural algorithm for intertemporal choice

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Using model-based fMRI, we have shown that neural activity in three regions (ventral striatum, medial prefrontal and posterior cingulate cortex) is correlated with the subjective value of all rewards during intertemporal choice. One limitation of model-based approaches, though, is that the data are often consistent with numerous models. For this reason, economists often use a more axiomatic approach to model-building, employing a series of simple empirical tests that sequentially strengthen the logical constraints on the family of models compatible with the data. Here we adopt a similar approach to constrain the function that best describes value-related neural activity in these three regions during intertemporal choice.

In two new experiments, subjects chose between immediate and delayed monetary rewards while we examined brain activity using fMRI. In the first experiment, there were two conditions: "immediate," involving choices between \$20 now and a larger delayed reward that changed on each trial, and "delayed," constructed by adding a delay of 60 days to all options in the first condition. In the second, the monetary amounts of both options in the delayed condition were increased over those in the immediate condition. In both experiments, mean neural activity did not differ between the two conditions, only the range of modulation by trial-to-trial changes in subjective value differed. In the first experiment, the modulation of neural activity was larger in the immediate condition. In the second experiment, the degree of modulation was similar when the amounts were greater in the delayed condition.

These findings rule out three classes of neural activation functions: i) those that predict mean activity should be greater for the immediate condition when monetary amounts are the same, ii) those for which activity is only a function of the relative delay from a reference point, rather than the absolute delay from the present, and iii) those that include any form of divisive normalization, where the value of one option is divided by the value of another. One of the few functions consistent with these constraints is one where neural activity reflects the exponentially present-discounted value of the larger-later reward minus the exponentially present-discounted value of the smaller-sooner reward. This function is interesting for two reasons: first, the subjective value of the soonest reward is used as a reference; and second, this difference in value could easily serve as a single decision variable that determines choice. These results illustrate the usefulness of a more axiomatic approach to model-based fMRI.

Title: The neural basis of intertemporal choice for self and other

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Offered the choice between two monetary rewards, most people would prefer \$10 today over \$12 in a week, while only few would prefer \$10 in a year over \$12 in a year and a week. Many behavioral studies so far found that humans behave dynamically inconsistent and irrationally when making such monetary decisions. McClure et al. (2004) investigated the neural basis of monetary intertemporal choices and found that, when given the choice between a smaller but sooner and a larger yet later monetary reward, subjects showed different neural activation patterns when they made their decisions: While only choices in which an immediate reward was offered were accompanied by activation in highly reward- and emotion-related limbic brain areas, the lateral prefrontal and posterior parietal cortex were activated by all decisions.

In our study, we investigated if there would be less limbic activation while making decisions one is less personally involved in, and if this would lead to more rational choices.

Applying the paradigm by McClure et al. (2004), we examined the neural activation when subjects made intertemporal choices between monetary rewards for another, unknown person, and compared it to choices subjects made for themselves. We found that when an immediate reward was included in the choice set, intertemporal choices made for oneself were indeed accompanied by activation in highly emotion- and reward-related areas, such as the pregenual anterior cingulate cortex, the ventral striatum and the precuneus. However, none of these areas showed elevated activation when making such choices for another person. While this is in accordance with our hypothesis concerning the neural correlates of intertemporal choices for self and other, we did not find any behavioral differences in the choices the participants made for themselves and others: In both cases subjects chose the smaller, but sooner, reward more often if it was available immediately.

To investigate these discrepancies between choice and neural activation in detail, we splitted our sample into two groups, depending on subjects' individual discount values. Within the group of subjects who discounted future rewards more strongly, we could find the same differences in neural activation patterns between self and other as before: Limbic areas were highly elevated for choices including an immediate reward for self only. In accordance with these neural activation differences, we also found behavioral differences between decisions for self and other in this group of strongly discounting subjects: They more often chose the larger, later reward for the other person than for themselves. This shows that at least subjects who discounted future rewards very strongly for themselves chose more rationally for others.

Title: Dissociating uncertainty and delay in inter-temporal choice

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Nearly all real-world decisions result from a complex interplay of multiple factors. For example, previous work has shown that rewards available only at some point in the future are less valuable than those same rewards available immediately, a phenomenon known as temporal discounting. The further into the future a reward is, the less valuable it becomes. Other work has shown that uncertainty has similar effects on decisions; the more uncertain a reward is, the less valuable it becomes. The similar influence of uncertainty and delay has led some to suggest that it is the uncertainty inherent in waiting for rewards that could, in part, explain temporal discounting. Though delay and uncertainty elicit similar behavioral effects, it remains unclear whether there are separate neural circuits that mediate the effects of reward delay and uncertainty, or whether there is a single circuit that underlies both phenomena. To investigate this question we carried out a functional magnetic resonance imaging (fMRI) experiment utilizing a novel variant of the inter-temporal choice task. In each trial, subjects chose between two different gambles, each with potential monetary rewards. In the immediate condition, the actual outcome was revealed immediately after the subject made their choice, whereas in the delayed condition, subjects had to wait the chosen delay during which the reward could be forfeited according to a constant hazard rate. Our task differs from traditional inter-temporal task in two important ways. First, our task utilizes stochastic reward delivery. This feature allows us to use an isomorphic, risky choice task (without delay) as a control and thus isolate the temporal aspects of inter-temporal choice. Second, in our task, participants had to actually wait the chosen delay and received the available reward on every trial. This creates a more naturalistic methodology and brings it in line with previous work in non-human animals. Our subjects were scanned as they performed both the immediate and delayed version of the task. Though the rate of discounting varied across subjects, behavior on the two tasks was highly correlated within individuals. Nonetheless, we found that a set of brain regions, including posterior cingulate and dorsolateral prefrontal cortex, exhibited different patterns of neural activity during the delay and immediate conditions. Activity in regions such as anterior cingulate and anterior insula was modulated by the subjective value of the rewards whereas activity in regions such as dorsolateral prefrontal and parahippocampal cortex was modulated by the magnitude of the delay itself (but not uncertainty). These differences suggest that there are neural circuits that are differentially involved in the temporal considerations unique to inter-temporal choice.

Title: The neural substrates of probabilistic and intertemporal decision making

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Many important decisions involve outcomes that are either probabilistic or delayed. Based on similarities in decision preferences, models of decision making have postulated that the same psychological processes may underlie decisions involving probabilities (i.e., risky choice) and decisions involving delay (i.e., intertemporal choice). Equivocal behavioral evidence has made this hypothesis difficult to confirm or reject. However, a combination of functional neuroimaging and behavioral data may allow identification of differences between these forms of decision making, reflecting recruitment of distinct cognitive processes. Here, we used functional magnetic resonance imaging (fMRI) to examine brain activation in subjects making a series of choices between pairs of gambles that differed either in their relative risk or their relative delay. A separate psychophysical procedure provided independent estimates of subjects' preferences for or aversions to risk and delay. Comparison of brain activation during decision making revealed that many of the same regions were active during both types of choices - these included the posterior parietal cortex, the dorsolateral prefrontal cortex, the orbitofrontal cortex, and the anterior insula - with greater activation to risky than to intertemporal choice. The differences between activation in the two conditions were most significant in the bilateral anterior and posterior intraparietal sulcus and the right middle frontal gyrus. Regression analyses indicated that these activation differences did not result from differences in task difficulty, as operationalized by response time. Also, the activation to risky choice was correlated with subjects' risky preferences in anterior insular and lateral prefrontal cortices, with more risk-averse subjects showing greater activation. Delay aversion was correlated with activation to intertemporal choices in the same regions. were correlated with subjects' economic preferences. Combined, our results indicate that there are qualitative differences in the patterns of brain activation evoked by risky and intertemporal choices, suggesting that the two domains utilize separate but overlapping sets of psychological processes.

Title: Other-Regarding Behavior and Neural Systems of Social Perception

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In a recent study, we demonstrated that the tendency towards other-regarding behavior is predicted by neural activity in the right superior temporal cortex (rSTC). This region is consistently activated during social perception tasks that require the prediction of another agent's behavior or the attribution of mental states, as well as during simple auditory and visual attention tasks (e. g., target detection, oddball). The breadth of tasks activating this region facilitates limited inferences about the nature of the computation it is performing. Further, most studies report functionally derived coordinates based on averages across many subjects, possibly obscuring individual differences in the spatial locations of functionally specific neural tissue. To address the question of whether these different tasks are recruiting different cognitive processes and regions of the brain, we presented subjects with a battery of visual attention and social perception tasks. We were also interested in whether individual differences in low-level perceptual abilities predict intersubject variation in other-regarding tendencies, or if this relation is only manifest when looking at high-level aspects of social perception. To explore the possibility that functional regions are spatially heterogeneous across subjects, we also obtained functionally defined regions of interest for each subject for each of our perceptual tasks.

Our results confirmed previous findings that the STC is preferentially activated by intentional movements more than random movements. We also replicated our previous finding that STC amplitude predicts individual differences in other-regarding tendencies. We observed the novel result that STC amplitude was also predicted by the ability to discriminate the degree of contingency between two objects' motion. Further, we extended our previous results by showing that the capacity to discriminate movement contingency was correlated with self-reported helping behavior.

Title: Amygdala activation during delay discounting in abstinent methamphetamine dependent individuals

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Methamphetamine (MA) dependent individuals prefer smaller immediate over larger delayed rewards on Delay Discounting (DD) tasks. Human and animal data implicate amygdala, ventral striatum, ventrolateral prefrontal cortex (VLPFC), dorsolateral prefrontal cortex (DLPFC), anterior cingulate cortex (ACC) and posterior parietal cortex (PPC) as candidate brain regions active in DD decisions. We used functional Magnetic Resonance Imaging (fMRI) to probe the neural correlates of performance on DD and control task in 19 recently abstinent MA dependent patients and 17 age and gender matched controls, then created statistical maps of correlations between brain activation, behavioral measures and group membership. Hard DD choices were associated with greatest activation in bilateral middle cingulate cortex (MMC), PPC, and the right rostral insula, Control subjects showed more activation than MA patients bilaterally in the precuneus and in the right caudate nucleus, ACC and DLPFC. Magnitude of discounting was correlated with activity in the amygdala, DLPFC, posterior cingulate cortex and PPC. Activation of the amygdala during choice of delayed reward was associated with a greater degree of discounting, suggesting that MA dependent individuals may be more responsive to the negative salience of delayed rewards than controls.

Title: Neuroimaging study for the effect of painting's information on aesthetic preference for contemporary painting

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Aesthetic preference for paintings is the outcome of complex cognitive processes based on personal experience and memory. As appreciation of contemporary paintings requires pre-requisite knowledge on painter's style and philosophy as well as basic comprehension of contemporary arts, some contemporary works are beyond our understanding. The current study aims at assessing the effect of painting's information on aesthetic preference for the contemporary paintings. We showed 8 contemporary paintings (Jackson Pollock, Jasper Jones, Paul Klee, Damien Hirst, Yves Klein, Barnett Newman, Gehard Richter, and Victor Vasarely) to 116 participants with paintings' information including the artist name, the subject of the work, the comments from the artist and a reviewer, and the highest bid price. Aesthetic preference was evaluated by questionnaires. We found that their aesthetic preference was significantly increased as the amount of given information was increased, particularly for the comments from painters and reviewers. Furthermore, we scanned event-related fMRI images from 17 subjects as painting's information is offered during appreciation of 6 paintings. Several regions including right superior frontal gyrus, anterior cingulate, and left putamen exhibited significant activations during the appreciation and their activation intensities were positively correlated with self-rated aesthetic preference. These findings suggest that aesthetic preference for contemporary paintings can be enhanced by painting's informations, particularly resonant informations like comments of painters or reviewers about the painting.

Title: Impairments in decision-making under ambiguity and risk in alcohol dependence

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Abstract text (fill no more than this page)

The neuropsychological origin of impaired decision-making in alcohol dependence is a critical issue in the field of neuroeconomics as well as psychiatry. It has been reported that alcohol-dependent patients exhibit significant deficits in intertemporal choices and motivational balance, particularly for reward. However, it is still unclear how they make decisions under conditions of ambiguity and risk. In the current study, we used the Iowa Gambling Task (IGT), which assesses the role of emotional feedback in reward and punishment under ambiguity, and the Game of Dice Task (GDT), which allows us to simulate decisions under risk in everyday life, to investigate a decision-making process of patients with alcohol dependence under conditions of ambiguity and risk.

Although IGT reflects several aspects of complex decision-making processes including working memory, motivational balance, reversal learning, risk perception, and attention shift, the correlation between performances in late trials of IGT and GDT can provide us with insight into the valuation of probability distributions. 80 patients with alcohol dependence and 75 healthy subjects were recruited to perform IGT and GDT, and their temporal choice patterns for two tasks were compared.

We found that alcohol-dependent patients exhibited significant correlations between performances of GDT and late trials of IGT compared with those of healthy subjects. This finding indicates the delayed calculation of probability distributions during IGT. We suggest that the delayed calculation of probability distributions under ambiguity and risk conditions can be an alternative component of disturbed decision-making in alcohol dependence.

Title: Neuropsychological mechanisms of odd-pricing effect

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Odd pricing or 99 pricing is one of prevalent pricing strategies in which the rightmost number of price ends with 99 (e.g. \$3.99). Several marketing studies have shown that odd pricing increases demands and promotes purchase of goods. Although several possible mechanisms have been proposed to explain this effect (for instance, drop-off mechanism suggesting that consumers tend to ignore ending digits of the price due to cognitive cost and direct their attention to leftmost digits), its neuropsychological origin is still unknown. The aim of this study was to understand the neuropsychological mechanism underlying the odd-pricing effect. We investigated (1) if consumers exhibit significant preference to buy goods of 99 prices compared with identical goods with higher or lower prices during behavioral experiment, (2) which brain regions are activated and inactivated during choice behavior of goods with 99 prices and non 99-prices using fMRI recordings, and (3) whether or not the degree of visual attention on 99 digits in price tags, measured from an eye-tracking system, is correlated with the degree of preference for 99-price goods. In the behavioral task, 35 subjects were provided with \$20 to buy their favorites among 50 chocolates with diverse price endings and their purchase behavior on identical chocolates with different price tags was compared. We found that the subjects exhibited significant preference for chocolates with 99 price endings, compared with the identical ones with 00 or 95 price endings. Successive neuroimaging and eye-tracking experiments are performed for 30 subjects. Taken together, this investigation will provide us with insights into how customers respond to price information, particularly 99 pricing, and the potential role of pricing strategy in the realm of neuromarketing.

Title: Differential neural mechanisms underlying temporal discounting of financial gain and loss

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Myriad experimental and theoretical studies have shown that delayed rewards are temporally discounted and that two major brain regions are involved in the intertemporal choices of primary and secondary rewards: emotional, delay-sensitive limbic regions and cognitive, time-insensitive dorsolateral prefrontal/posterior parietal regions. It still remains elusive if the common neural circuits respond to immediate punishment or delayed punishment. In the perspective of exponential discounting, decay rate of monetary loss has been shown to be smaller and to decrease more slowly than those of monetary gain, as delay is lengthened. In this study, we investigate whether or not the shape and steepness of the discount function in the aversive frame is different from in the appetitive context. 30 healthy subjects were recruited to perform a two-alternative forced selection task, in which subjects experience real, not hypothetical, positive and negative monetary outcomes with the corresponding delay in each session. We found that the majority of the subjects adopted different discount strategy according to valence of the outcome, albeit consistent discount policy within one of positive or negative contexts. No universal patterns of selecting exponential or hyperbolic discounting in each frame were found. In the fMRI measurements, we are investigating neural substrates underpinning this differential time preference for financial gains and losses. Hence, the findings of this experiment allow us to shape better understanding about the critical issue whether or not the temporal discounting of monetary loss is mediated by the interactive contributions of the similar neural circuits with the specific discount function which might produces the heterogeneous intertemporal choices of individuals.

Title: The Influence of Emotion Regulation Strategies on Risky Decision-Making

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Introduction In daily life, emotions can cloud judgment leading to impulsive decisions with potentially negative long-term outcomes. While this effect is most apparent with negative emotions (e.g., fear), positive emotions can also have a strong influence on behavior. The hedonic feelings associated with a positive conditioned stimulus (e.g., a lottery ticket), for example, may propel one's behavior towards the "reward" (e.g., buying a ticket in hopes of getting the big jackpot). Typically, the influence of positive emotions on decision-making is harmless and even advantageous, but when craving intensifies, as is the case in addiction, it can lead to maladaptive risk-taking behavior as observed in drug-seeking. Thus, it is imperative to understand the mechanisms involved in the regulation of positive emotions to achieve less impulsive and more goal-directed decision-making in daily life. The goals of this study were: 1) to examine how cognitive emotion regulation strategies modulate positive emotions elicited by a conditioned stimulus (CS); 2) to examine the effect of regulation on subsequent decision-making and on the neural systems of appetitive conditioning.

Methods To investigate these questions we studied gambling behavior in healthy individuals. We employed a functional magnetic resonance imaging (fMRI) conditioning-based paradigm in which a CS, a colorful picture of a slot machine, represented a reward-seeking opportunity. Participants were faced with a choice between a gamble (e.g., 50% chance of \$20) and a sure thing (\$5). Prior to CS presentation, an instructional cue directed participants on how to approach each trial. When the instruction was "attend" they were to think about winning money during CS presentation (attend condition). When the instruction was "regulate" they were to use the colors in the slot machine image to help them imagine a calm visual scene (e.g., a sunset) during CS presentation (emotion regulation condition).

Results & Discussion Emotion regulation strategies influenced different aspects of decision-making. Specifically, participants took longer to make a decision and chose the gamble option significantly less during the regulation compared to the attend condition, suggesting that when participants used emotion regulation they were less impulsive and less risky. In support of the behavioral results, preliminary fMRI analysis focused on differences between the attend and regulate conditions during CS presentation. Two critical regions for appetitive conditioning and emotion processing, namely the amygdala and striatum, were examined. We found that BOLD signal in these regions was modulated by emotion regulation strategies. That is, increases in BOLD signal typically observed for the positive CS (the slot machine) were decreased during the regulation compared to the attend condition. Overall, our results suggest that cognitive emotion regulation strategies can effectively decrease impulsive behavior by reducing positive emotion or craving/anticipatory feelings associated with the conditioned stimulus. Potential implications for risky financial decision-making and addictive behaviors will be discussed.

Title: Acute Stress Modulates Risk Sensitivity in Financial Decision-making

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Day to day decision-making is susceptible to various demands exerted by the environment. At times, such demands can lead to stressful conditions, affecting both psychological and physiological states. While a goal for researchers is to understand how to control stressful conditions while making informed goal-oriented decisions, the first step is to probe the interaction between the state created by a stressful environment and how decisions are performed in such environment. The goal of this experiment was to a) elucidate the impact of exposure to acute stress on financial decision-making and b) examine the particular influence of stress on positively and negatively framed decisions. Prospect Theory has identified a pervasive bias in human decision-making, such that risk sensitivity varies with the framing of a specific decision, that is, people are risk-averse for positively framed decisions and risk-seeking when decisions have a negative valence. Using Prospect theory as a platform, we hypothesize that under stress participants will come to further rely on the innate framing-dependent decision-making heuristics it posits.

The experiment involved a series of financial decisions (i.e., gambling) both before and after exposure to acute physiological stress (i.e., cold pressor task). Stress was induced by immersion of the participant's dominant hand in ice cold water (4° C) for two minutes. The "no-stress" control condition required immersion of the hand in room temperature water (25° C). After each immersion, participants were presented with a gambling task involving a choice between two alternatives of equal expected value, but varied probability. On a given trial, both choices were framed as either a possibility to "win" or to "lose" money, permitting the collection of risk sensitive decisions in both positive and negative contexts. Finally, galvanic skin responses (GSR) were acquired during both "stress" and "no stress" blocks of gambling trials as a measure of physiological arousal. This experimental paradigm therefore allowed us to probe the interaction between an individual's physiological state (Stress x No-stress) and the framing of decisions (Win x Loss).

Results indicated that the stress manipulation was successful, as participants overall GSR levels were higher during the stress compared to non-stress decision-making blocks. As expected, choice behavior conformed to Prospect Theory's predictions during no-stress blocks. That is, participants were more risk-averse during trials where choices were framed as a possible win, and more risk-seeking when choices were framed as a possible loss. Exposure to acute stress significantly modulated participants' behavioral tendencies with respect to reaction time and strategy. Specifically, participants were more impulsive overall under stressful conditions, generating faster and extreme responses with respect to their natural behavioral tendencies. The observed interaction between an individual's physiological state and the framing of decisions suggests that exposure to stress may influence decision-making tendencies favoring over- or under-weighting of more probable events beyond the standard predictions of Prospect Theory. Hence in our experimental paradigm, acute stress leads to impulsive decisions, where individuals rely significantly more on the innate framing-dependent decision-making heuristics postulated by Prospect Theory.

Title: Stress, drugs, dopamine and risk taking

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Utility theory supposes that given a choice between gambles, rational individuals will pick the gamble with a greater expected utility, or average outcome. The expected utility is the sum of all possible payoffs of a gamble, weighted by their probability. Often, given the choice between gambles, individuals will behave in a less than rational manner. Individuals are risk averse when they forgo riskier gambles, with low probability of reward, even when the average payoff is the same or greater than that of a safer gamble. Conversely, risk prone individuals will forgo safe gambles, with high probabilities of reward, even when the average outcome is the same or less than that of a riskier gamble.

Several lines of evidence indicate that expected utility might be represented in the brain by the rate of firing of VTA dopamine (DA) neurons in response to reward-predictive cues learned through operant or classical conditioning. It is therefore likely that perturbations of DA release within limbic cortical areas and the ventral striatum, also known as the Nucleus Accumbens (NAc) in rodents, will disrupt the individual's representation of expected utility, and subsequently modify his or her risk tendency. Such perturbations include but are not limited to drug use, drug addiction, and stress. We hypothesize that an individual's affinity or aversion to risk is modulated heavily by stress, drug use and other factors that influence limbic DA release.

To investigate how DA neurons are directly modulated by stress, we studied the effects of the stress-related peptide, corticotropin releasing factor (CRF) directly applied to the VTA. Fast-scan cyclic voltammetry (FSCV) was used in awake, behaving rats to record the effect of intra-VTA corticotropin releasing factor (CRF) injections on NAc DA release. In some experiments rats were trained on a 2-armed bandit to examine whether cue evoked NAc DA release does represent expected utility and whether perturbations of this system with CRF or DA reuptake blockers affects this representation and/or risk tendency. Our results suggest that CRF can directly modulate limbic DA release and that this modulation is linked to a change in risk tendency.

Title: Decision making under ambiguity: Behavior and neurobiology.

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In situations that involve ambiguity most human decision makers are sensitive to the amount of ambiguity. Lower ambiguity is generally preferred, although the reverse is not uncommon. Such ambiguity sensitivity is often modeled in terms of alpha-maxmin utility theory, which is essentially an extension of expected utility theory where beliefs are anchored relative to the worst-case and/or best-case scenarios. Here, we propose an alternative approach, whereby preferences are modeled in terms of a trade-off between expected payoff (at uninformed priors) and the amount of ambiguity in the available options. We first compare the relative power of the two approaches to predict subjects' behavior in a simple choice paradigm with varying levels of ambiguity. Using parameter values estimated from the behavioral data, we subsequently determine which model best fits brain activation as recorded through fMRI monitoring of subjects during the task. We focus on brain regions that are known to be differentially engaged in situations involving ambiguity (Hsu et al 2005).

Title: The use of probability in decision making under risk compared to an equivalent motor task

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Recent research has shown that in motor tasks equivalent to decision making under risk, humans select movement strategies that come close to maximizing expected gain (See Maloney et al., 2007 for review). In contrast, subjects in 'classical' decision making tasks exhibit large, patterned deviations from optimal performance. In these tasks, subjects choose among lotteries that differ in the distribution of probabilities across possible outcomes. An evident difference between the motor and classical task is the source of probability information. The probability distributions in the classical task are selected by the experimenter. In the equivalent motor task, the probabilities are generated by the subject's own stochastic variation in movement. We considered the hypothesis that subjects' near-optimal performance in motor decision making is due to the difference in the sources of uncertainty in the two tasks. Based on previous work we cannot reject this hypothesis. The experiments employing motor tasks differed in many respects from those of typical decision making experiments intended to investigate 'one shot' decision making.

Method. We replicated the common consequence tasks used by Wu and Gonzalez (1996) both as a motor task and a decision making task with identical trial by trial experimental designs. We replicated the original experiment with the probabilities of outcomes *explicitly* given in the lotteries ('classical' lottery task) and we also replicated the experiment with each lottery translated into an equivalent motor task ('motor' lottery task) where the probability of each outcome is *implicit* in visuomotor uncertainty. To elicit the probability weighting function in the classical and the motor domain individually, each subject ran both the classical lottery tasks and the motor lottery tasks. On each trial in both conditions subjects indicated which lottery they preferred. They knew that at the end of the experiment, they would be allowed to attempt only one of their preferred classical lotteries and one of their preferred motor lotteries chosen at random and receive the outcome. We used maximum likelihood methods for estimating the parameters of the probability weighting functions and testing hypotheses concerning these parameters using resampling methods to estimate confidence intervals of the parameters.

Results. Eight naïve subjects participated in the experiment. All subjects violated the independence axiom in the classical tasks with a pattern consistent with Wu and Gonzalez, while five out of eight subjects did not violate the axiom in the motor tasks. Moreover, seven out of eight subjects showed a smaller degree of deviation from the independence axiom in the motor version. Our results indicated that decision under risk in the motor domain differs from that in the classical domain in how choosers make use of probability information.

Title: Nucleus accumbens activation mediates the influence of incidental reward cues on financial risk-taking

Authors: G Elliott Wimmer, Camelia M Kuhnen, Piotr Winkielman, Brian Knutson

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Abstract text (fill no more than this page)

Spontaneous increases in endogenous nucleus accumbens (NAcc) activity precede switches from financially risk-averse to risk-seeking choices. Since anticipation of diverse rewards activate the NAcc, incidental reward cues might alter financial risk taking. We used event-related fMRI to determine whether anticipation of viewing highly rewarding stimuli (i.e., erotic pictures for heterosexual males) would increase subsequent financial risk taking, and whether this effect would be mediated by increased NAcc activation. Indeed, anticipation of viewing rewarding stimuli increased subsequent financial risk taking, and this behavioral effect was mediated by anticipatory increases in NAcc activation. These results are consistent with the notion that incidental reward cues can influence financial risk taking by altering anticipatory affect. Thus, the findings identify a mechanism that may account for the efficacy of some emotional appeals in financial, marketing, and political domains.

Title: The utility of voting: Neural correlates of expressive voting

Authors: Carolin Neuhaus^{1,2}, Ivo Bischoff³, Bernd Weber^{1,4}

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In economic theory, voters are considered rational agents who maximize expected utility. When deciding which party to vote for or whether to approve or reject a proposal, they choose the course of action which yields the higher expected utility. Different sources of utility are discussed in the public choice literature. Instrumental voters use the vote as an instrument to influence public policy thus choosing the policy proposal which yields the highest utility if pursued. The theory of expressive voting argues that a voter cannot expect to be decisive. Therefore, the utility which motivates him to cast his vote in a certain way must result from the act of voting itself rather than from the outcome of the election or ballot while the utility he expects if the proposed policies are pursued is of minor importance.

We conducted an fMRI experiment which investigates neurophysiological activation in the moment of expressing ones opinion. The set-up is closely related to the behavioural experiment of Tyran (2004). The subjects are endowed with some amount of money and are asked to vote on a proposal to keep the money or donate the endowment of all participants to charity. If the overall approval rate exceeds a certain quorum Q , the proposal is accepted, else it is rejected. For each Q , subjects are presented approval rates obtained in a prior behavioural study.

In a first pilot testing with 9 healthy male subjects, we find that the observed approval rate among all subjects depends on the value of Q . Participants' behaviour is in line with expressive voting and preliminary results of fMRI analysis show coherent neurophysiological activation in the ventral striatum and amygdala. Both types of result suggest that voting with the majority of others is the primary reward behind the choice-utility of so-called switchers.

Title: **Paracingulate cortex activates when reading the "mind" of financial markets with potentially beneficial or harmful insider information**

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Paracingulate cortex (PCC) activation in the human brain has been associated with the task of predicting benevolent (McCabe et al.) or malevolent (Gallagher et al.; Bhatt-Camerer) intentions in the mind of one's opponent in strategic games, an activity known as "mentalizing." To date, it is not known to what extent this role of PCC extends to situations where one faces a social system as opposed to a single human being. Here, we hypothesized that PCC is also involved in inferring to what extent engagement in a social system will be harmful or helpful to one's own situation. The classical example is that of financial markets with insiders. To test our hypothesis, we re-played financial markets to subjects who were exposed to the risk of the traded securities. Using functional magnetic resonance imaging (fMRI), we scanned subjects' brains while they were watching the order and trade histories. Across market histories, we changed only the extent to which prices revealed information relevant to the subjects. We could do so because our financial data were generated in prior, fully controlled markets experiments. Significant ($p < 0.001$, uncorrected) PCC activation emerged. The only other regions that activated at $p < 0.001$ were anterior cingulate cortex (ACC), insula, and amygdala, structures known to be involved in general learning tasks. Our findings are significant for several reasons. First, our results extend the role of PCC from inferring the intentions of another person to reading the "mind" of a social system. This finding may be interpreted as evidence that subjects anthropomorphize financial markets with insiders, yet we find no evidence of explicit anthropomorphization. Instead, we conjecture that PCC activation emerges in situations where subjects may attempt to influence the situation, although in the case of our financial markets, this is but an illusion of control, as the competitive nature of these markets make it hard to single-handedly change the beliefs of others. Illusion of control is, of course, a well-established psychological phenomenon (it may explain, e.g., why people vote in large elections), but its scope (range of applicability) has yet to be defined. Second, the experimental design is such that it disentangles whether PCC activation is merely associated with situations involving a human opponent (or an anthropomorph phenomenon) against situations featuring distinctly non-human interaction (play against a computer; viewing of random patterns - Gallagher et al., Castelli et al.), or whether PCC activation correlates with learning of the beliefs and intentions of others (singly or as a social system). Unlike prior studies, there is an equal human component in our baseline treatment. As such, our results suggest that PCC engagement does not merely define when the brain considers the structure it faces in the outside world to be "human" or "human-like." Third, our results demonstrate that PCC correlates with the extent to which financial markets reveal information relevant to one's own situation. The mere presence of insiders is not sufficient for PCC involvement; only when insiders have relevant information does PCC become engaged, reinforcing the idea that PCC activation reflects learning. Finally, the similarity of brain activation in games with a single human opponent and in financial markets with insiders suggest that financial market participation is not unlike playing strategic games. This finding may have profound implications for financial theory, which strictly separates these two activities. Indeed, the theory of finance considers financial market participation to be equivalent to games against nature, such as simple single-person card guessing games (Preuschoff et al.) or reversal learning tasks (Hampton et al.), where probabilities cannot be manipulated, but where significant PCC activation has yet to be observed.

Title: The Origins of Anchoring and Adjustment: Biased Numerical Estimations in Non-Human Primates

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Abstract text (fill no more than this page)

In order to make decisions, all organisms must (at some level) estimate unknown quantities and values. In some cases, the computational demands of accurately estimating numerical values might favor the use of heuristics, ones that on average approximate correct values but do so with some inherent noise. Human adults employ a number of such heuristics, one of which has come to be known as the process of "anchoring and adjustment." When using anchoring and adjustment, decision-makers begin the task of estimating unknown quantities by starting with a known or guessed quantity (the 'anchor') and 'adjusting' it until a reasonable total is reached. An interesting, and not fully understood, property of this strategy is that the final estimate produced is shifted in the direction of the anchor. Psychologists have long observed this pattern of bias in adult human participants. Although much is known about anchoring and adjustment at the behavioral level, little work has addressed the neural basis of this heuristic. In addition, we know relatively little about the origins of this anchoring bias. Can the anchoring bias be attributed to the linguistic or contextual demands of decision-making? Or is it the product of simpler, perhaps evolutionarily older constraints on numerical estimation? Here, we show that free-ranging rhesus macaques (*Macaca mulatta*) demonstrate biased numerical estimations consistent with the signatures of anchoring and adjustment. Using a looking time paradigm, we demonstrate that monkeys' expectations about the number of strawberries placed into a box is biased by the initial number they see entering the box. This finding suggests that anchoring and adjustment is a relevant strategy for non-human primates and thus that the origins of this strategy are evolutionarily ancient. These findings are relevant to the current debate over whether to characterize decision-making biases as processing errors or evolutionary adaptations in their own right, since the debate is ultimately about the origins and ecological relevance of these cognitive biases. Moreover, these results provide a behavioral task for future studies to begin exploring the neural basis of this effect using primate neurophysiological techniques.

Title: Ventral striatum signals both social and nutritive rewards.

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All social animals face the choice of whether to interact with others or pursue the food and fluid needed to sustain behavior. In order to make this choice, the brain must integrate reward information from social and nutritive sources. The ventral striatum (VS) could play a key role in the initial stages of this integration. Imaging studies have implicated the VS in processing both nutritive and financial rewards, and electrophysiology studies have shown separate populations of cells in the VS represent rewards of different modalities. We therefore hypothesized that this brain structure would represent both nutritive and social rewards, and furthermore, non-overlapping populations of cells would represent these reward modalities. To test this hypothesis, we recorded from ventral striatum in rhesus macaques performing a "pay-per-view" choice task, as well as a passive reward task. The pay-per-view choice task permitted us to estimate the value of seeing images of other macaques and fluid rewards in a common metric. Previously, we demonstrated that male macaques value information about potential threats (represented by the faces of dominant males) and potential mating opportunities (represented by the hindquarters of females). We predicted that ventral striatum neurons would encode social and fluid rewards of the same valence and magnitude. Preliminary data support this hypothesis.

Title: Combining Brain and Behavioral Data to Improve Econometric Policy Analysis

Authors: Daniel Houser, Daniel Schunk and Erte Xiao

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For an economist, ultimate goals of neuroeconomic research include improving economic policy analysis. One path toward this goal is to use neuroeconomic data to advance economic theory, and productive efforts have been made towards that end (see, e.g., Camerer, et al., 2005). Equally important, though less studied, is how neuroeconomics can provide quantitative evidence on policy, and in particular the way in which it might inform structural econometric inference. This paper is a first step in that direction. In particular, we suggest here that key forms of preference (or decision strategy) heterogeneity, increasingly recognized as important to structural econometric policy analysis (e.g., Houser, 2004), can be identified by brain imaging studies and, consequently, linked stochastically to observable individual characteristics. Then, recognizing that brain-imaging studies can be substantially costly in both time and money, we derive conditions under which relationships between a person's observable characteristics and their type can be estimated more precisely by combining data from traditional and brain-based decision studies.

Friday, September 28, 2007, continued

Risk

| | | | |
|----------------|---|---|---|
| 4:00 – 4:30 pm | Peter N. C. Mohr | Risk-value trade-off in investment decisions | Peter N. C. Mohr, Guido Biele, Lea Krugel, Shu-Chen Li, Hauke Heekeren |
| 4:35 – 5:05 pm | Benjamin Hayden | Understanding the role of salience in risky decision-making | Benjamin Y. Hayden, Allison N. McCoy, Amrita Nair, and Michael L. Platt |
| 5:10-5:40 pm | Ifat Levy | Neural correlates of subjective value under risky and ambiguous decision-making | Ifat Levy, Aldo Rustichini, and Paul W. Glimcher |
| 5:45 – 6:15 pm | Mathieu d'Acremont | Risk prediction in the human brain: A functional neuroimaging study | d'Acremont, M., Lu, Z.-L., Li, X., and Bechara, A. |
| 7:00 pm | Dinner—New England Clambake Hull Yacht Club* | | |

*Dinner is offsite—shuttles will be provided to those who don't have transportation

Title: Risk-Value Trade-Off in Investment Decisions

Authors: Peter N. C. Mohr [1,2], Guido Biele [1,2], Lea Krugel [1,2], Shu-Chen Li [3], Hauke Heekeren [1,2]

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A common class of models in financial decision-making, namely Risk-Value Models, makes the assumption that there is a trade-off between the value of an investment and its risk (e.g. Sarin and Weber, 1993). The most prominent realization is the expected return – variance of return rule, which uses the expected return as the value of an investment and the variance of returns as its risk. This study investigated neural correlates of risk and value perceptions. As a main result we can identify neural correlates of perceived risk and return, which we predict with simple mathematical models.

Thus far, neuroimaging studies on risky decision making have mainly focused on gambles rather than concrete investment decisions. Yacubian et al. (2006), for example, used a guessing task where subjects had to guess which of 8 cards is red, and manipulated the risk of the decision by varying the probability of winning. Only few studies used the variance of outcomes to manipulate risk (e.g. Preuschoff et al., 2006). However, in real-life investment decisions investors are seldomly faced with concrete probabilities and discrete magnitudes of outcomes. Instead, they are usually confronted with past performance data of investments. Additionally, recent behavioral studies indicate that the variance of returns might not be the best model for risk perceptions of investors (e.g. Klos et al, 2005). Therefore, the goal of this study was to test whether results about the neural representation of value and risk also hold in more ecologically valid situations, where people have to infer risk and expected return instead of being provided with objective values. Specifically, this study used a new approach to induce perceptions of risk and value. We sequentially presented the subjects a stream of 10 returns of an investment instead of a probability to win and the magnitude of the outcome. These 10 returns can be seen as past returns (e.g., either on a monthly or yearly interval). After viewing these returns subjects (n=19) had to answer 1 of 3 questions, without knowing in advance which one. Subjects were either asked for (1) their perceived expected return of an investment with the returns they just saw, (2) their perceived risk of the investment, or (3) a decision between an investment with the returns they saw and an investment with a fixed return of 5% (27 trials per condition).

Subsequently, the first two questions were used to model perceptions of risk and expected value individually. To predict participants risk perception we compared a range of models (among them the standard deviation and the probability of loss) with a cross validation procedure. The best model was coefficient of range (range divided by mean). For the perception of expected return, a model where returns under 5% were overweighted performed best (most often least cross-validation value).

However, after finding optimal individual models for risk perception and perceived expected value these two constructs remain unobservable variables during a concrete decision. Therefore we also examined the neural circuitry involved in making investment decisions using fMRI. We correlated predictions of the best models with brain activity during the decision between the investment with 5% fixed return and the investment represented by the return stream. We found significant correlations between the risk model and brain activity in the Insula and the Anterior Cingulate Cortex (ACC), a brain region, in which activity correlated with uncertainty in previous studies (Kuhnen and Knutsen, 2005). The model for expected return was correlated significantly with activations in the dorsolateral prefrontal cortex (DLPFC). These preliminary results indicate that there might be distinct neural representations of risk and value providing neuroimaging evidence for a Risk-Value trade-off in investment decisions.

Title: Understanding the role of salience in risky decision-making

Authors: Benjamin Y. Hayden, Allison N. McCoy, Amrita Nair, and Michael L. Platt

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Web address URL for a paper (if available):

Abstract text (fill no more than this page)

Animal and human decision-makers often behave irrationally in the face of risk, either preferring or avoiding options associated with uncertainty. Explaining risk-sensitivity remains a critical problem in economics. Here we report the results of three complementary behavioral and neural studies examining the hypothesis that risk-seeking reflects overweighting of the salience of the possibility of winning. Consistent with this idea, we find that in a gambling task that promotes risk-seeking, macaques are more sensitive to changes in the size of the large reward than to equivalent changes in the size of the small reward. We also find that neuronal responses in posterior cingulate cortex, a reward area, distinguish wins from neutral outcomes but do not distinguish equally different losses from neutral outcomes. Finally, we find that while decisions reflect the outcomes of the last few trials, wins lead to a 'reset' in behavior, suggesting that subjects 'anchor' their prospective estimates to wins. The complementary results of these experiments indicate that the salience of the win contributes to risk-seeking, and suggest that salience is a critical factor in explaining risk sensitivity.

Title: Neural correlates of subjective value under risky and ambiguous decision-making

Authors: Ifat Levy, Aldo Rustichini, and Paul W. Glimcher

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Abstract text (fill no more than this page)

Most people are averse to risk and ambiguity and the degree of those aversions vary substantially across different people. While substantial research in psychology and economics examined these behavioral phenomena, it is still unclear whether a common neural substrate underlies both sets of behaviors or whether multiple systems represent value under different conditions. Previous studies observed differences in neural activation when humans made choices under risk or under ambiguity, and argued for separate substrates for risk and ambiguity aversion. However, those differences in activation patterns may have been due to differences in the value that the risky and ambiguous choices had to the subjects and to the different behavior exhibited by the subjects when faced with risky and ambiguous choices. Here we equated the subjective value of lotteries under risk and ambiguity, and then looked for psychometric-neurometric matches separately for risk and ambiguity. 10 subjects participated in 2 fMRI sessions comprised of 360 trials. In each trial subjects had to choose between a reference lottery (50% chance of \$5) and a second lottery which was either risky or ambiguous. Three risk levels (0.13, 0.25 or 0.38) and 3 ambiguity levels (0.25, 0.5, 0.75) were used, each at 5 different amounts (\$5, \$9.5, \$18, \$34 or \$65). Six trials were randomly selected at the end of the experiment and were played for real money. The subjective value of each trial to the subject was estimated using a model with independent parameters for risk and ambiguity preference. Neural activation was then regressed on the subjective value estimate separately for risk and ambiguity trials. Activation in the medial prefrontal cortex, posterior cingulate and ventral striatum was correlated with the subjective risk-adjusted valuations of risky lotteries in each individual. Thus, these areas exhibited a psychometric-neurometric match for risk aversion. Neural activation in these same areas was also correlated with the subjective ambiguity-adjusted valuations of ambiguous lotteries. In contrast to previous studies which did not control for overall differences in the desirability of risky and ambiguous choice sets, the results suggest a largely unitary system for subjective valuation.

Title: Risk prediction in the human brain: A functional neuroimaging study

Authors: d'Acremont, M., Lu, Z.-L., Li, X., and Bechara, A.

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Abstract text (fill no more than this page)

In many situations, we have to take decisions without knowing the consequences in advance. But we can learn from past experience to anticipate future outcomes. This principle is formalized by the Rescorla-Wagner rule: (1) a reward is predicted, (2) the prediction is compared to the outcome to compute a reward prediction error and (3) the prediction is updated. Recently, it has been proposed that the brain may also be engaged in tracking risk by mean of risk prediction errors. Risk is defined as the variance of the outcome and risk prediction error is the difference between the predicted risk and the observed risk. **Aim:** To date, it is not known which brain regions encode risk prediction error in situations where individuals are free to choose between several options and need to learn reinforcement contingencies (uncertainty + ambiguity). **Hypothesis:** We made the hypothesis that the Striatum and the Insula could play such a role. **Method:** 8 adults completed 4 versions of the Iowa Gambling Task during fMRI. Decisions were modelled with reinforcement learning and individual parameters (learning rate and risk preference) were estimated by maximizing the likelihood with a local search method. Model fit was checked with parametric bootstrap. Brain activity after each decision was regressed on reward and risk prediction errors. **Results:** By order of importance, results showed that risk prediction errors covaried with activity in the Inferior frontal gyrus ($t = 6.21$) > Insula ($t = 5.67$) > Anterior cingulate ($t = 3.14$) > Amygdala ($t = 2.73$) > and Ventral striatum ($t = 2.14$, $p < .05$). From these regions, the Insula was the only one related to risk but not reward prediction errors. **Conclusion:** The hypothesis linking the Striatum and the Insula to risk prediction error is corroborated but it appears that other regions are involved. The Insula is the only region related to the prediction of risk but not reward. Results are in line with an insular view of anxiety characterized by a fear of risk. In addition, the Insula may signal the intensity of somatic states.

Saturday, September 29, 2007

8:30 – 9:30 am

Continental Breakfast

Women in Neuroeconomics breakfast

Rafael's

Aversive Processing

| | | | |
|------------------|------------------|---|---|
| 9:30 – 10:00 am | Mauricio Delgado | Aversive conditioning with secondary reinforcers: Fear of losing money? | Mauricio R. Delgado, Rita L. Jou, Elizabeth A. Phelps |
| 10:05 – 10:35 am | Scott Huettel | Unattractive faces and financial losses activate similar brain regions | David Smith, Benjamin Hayden, Michael Platt, & Scott Huettel |
| 10:40 – 11:10 am | Charles Noussair | Neurobiological regret and rejoice functions for aversive outcomes | Gregory S. Berns, C. Monica Capra, Pammi V.S. Chandrasekhar, Charles Noussair |

11:10 – 11:40 am

Coffee Break

Cognition & Economic Behavior

| | | | |
|------------------|---------------|--|----------------------------------|
| 11:40 – 12:10 am | Ellen Furlong | Why is the parietal cortex involved in economic decision making? | Ellen E. Furlong & John E. Opfer |
|------------------|---------------|--|----------------------------------|

Value & Preference

| | | | |
|------------------|--------------------|---|---|
| 12:15 – 12:45 am | Greg S. Corrado | fMRI in monkeys and humans engaged in a foraging task | G. S. Corrado, L. P. Sugrue, J. R. Brown, N. K. Logothetis, W. T. Newsome |
| 12:45 – 1:45 pm | | Lunch | |
| 1:40 – 2:10 pm | Hilke Plassmann | Marketing actions can modulate neural representations of experienced utility | Hilke Plassmann, John O'Doherty, Baba Shiv, and Antonio Rangel |
| 2:15 – 2:45 pm | Daniel Krawczyk | The emergence of product preferences: from early visual processing to preference-based choice | Daniel C. Krawczyk, Conrad Capili, Anson Chu, Jonathan Coker, Cressy Wang, & Julian Jamison |
| 3:00 – 3:30 pm | John R. Monterosso | Delay discounting based on activation in the ventral striatum | John R. Monterosso, George W. Ainslie, Edythe D. London |

Evening free, dinner on your own

Title: Aversive conditioning with secondary reinforcers: Fear of losing money?

Authors: Mauricio R. Delgado, Rita L. Jou, Elizabeth A. Phelps

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Abstract text (fill no more than this page)

Goal-directed behavior for all species is often influenced by biologically innate primary reinforcers such as food or water. In human society, money is a common good that is exchanged to acquire primary reinforcers. Money is therefore considered to be a secondary reinforcer, acquiring its value through association. Despite this intrinsic difference between primary and secondary rewards, neuroimaging studies of appetitive or reward processing often find overlapping regions of interest irrespective of type of reinforcer (e.g., juice or money), thus suggesting a common neural circuit involved in reward learning and decision-making. Less is known about the role of secondary reinforcers such as money during aversive processing. Across species, studies of aversive conditioning typically utilize primary reinforcers (e.g., shock) to induce fear and study the pathology of anxiety disorders. Many of society's maladies and anxieties, however, stem from monetary-related issues (e.g., loss aversion). Thus, it is imperative to understand if a secondary reinforcer such as money can influence basic mechanisms involved in aversive processing. The goal of this presentation is to: 1) investigate the efficacy of money during aversive conditioning, and 2) directly compare the influence of primary and secondary reinforcers on aversive conditioning and the underlying neural substrates of affective learning and decision-making (e.g., striatum, amygdala, insula).

Participants were invited to play a gambling game where they could win or lose money based on their performance. The purpose of the game was to provide a monetary endowment, ensuring that each participant had a certain amount of money in their "bank". Immediately following the gambling game, participants were subjected to two separate aversive conditioning sessions. In one session, a primary reinforcer (i.e., mild shock to the wrist) served as an unconditioned stimulus (US) and was paired with one of two colored squares, the conditioned stimuli (CS+ predicted possible shock; CS- predicted no shock). In another session, a secondary reinforcer (i.e., loss of money, -\$6.00) served as the US and was paired with one of two different colored squares (mCS+ & mCS-). During both fear conditioning sessions, delivery of the US was probabilistic and resulted in either 6 shocks or a total monetary loss of \$36.00. Thus, participants were exposed to a traditional conditioning session where shock was the reinforcer, but were also exposed to a second session where monetary loss served as the reinforcer. This design allowed for a comparison of common and distinct neural substrates underlying the influence of shock and money in aversive conditioning.

Skin conductance responses were higher for trials paired with an aversive outcome (CS+) compared to trials that were paired with no outcome (CS-). These results were observed irrespective of type of reinforcer, suggesting that a secondary reinforcer such as money can be an effective aversive US capable of influencing the physiological correlates of fear. Neuroimaging analysis revealed that regions in the striatum and cingulate cortex, previously involved in aspects of affective learning and anticipation of positive and negative outcomes, were commonly activated in the shock and loss of money conditioning sessions (CS+ vs. CS- trials for both primary and secondary reinforcers). Other areas typically involved in aversive conditioning and intensity feelings (e.g., insula, amygdala) were more strongly recruited during the shock compared to the loss of money trials, suggesting potential differences between the experienced intensity of the two reinforcers. Similarities and differences between types of reinforcers and the role of money in aversive processing will be further discussed, along with applications to decision-making.

Title: **Unattractive faces and financial losses activate similar brain regions**

Authors: David Smith, Benjamin Hayden, Michael Platt, & Scott Huettel

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Abstract text (fill no more than this page)

We have previously shown that the opportunity to view faces of attractive and unattractive people serve as positive and negative reinforcers, respectively. However, it remains unclear whether a single brain network processes decisions about monetary and social reinforcers. We used event-related functional magnetic resonance imaging (fMRI) to examine brain responses of heterosexual men to female faces that ranged from highly unattractive to highly attractive, based on normative data from an empirical database. Neuroimaging data were collected using a novel SENSE spiral-in imaging sequence through eight channels for improved spatial fidelity.

Subjects were presented with faces and with information about small, non-hypothetical, financial gains and losses while they performed a simple, unrelated task. Because so little is known about the differences in brain processing of different classes of aversive stimuli, we were especially interested in responses to unattractive faces and monetary losses. We found that unattractive faces and monetary losses both activated regions known to mediate reactions to aversive, disgusting, or painful stimuli. Specifically, highly unattractive faces contrasted against highly attractive faces activated the right insular cortex and the right frontopolar cortex as well as the right post-central gyrus. A parallel contrast between monetary losses and monetary gains revealed bilateral activation in the insular cortex and the amygdala in addition to the right post-central gyrus.

These results suggest that aversive social stimuli and monetary losses are mediated by similar cortical regions, and suggest that these areas participate in a domain-general network for signaling aversive events.

Title: Neurobiological Regret and Rejoice Functions for Aversive Outcomes

Authors: Gregory S. Berns, C. Monica Capra, Pammi V.S. Chandrasekhar, Charles Noussair

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Abstract text (fill no more than this page)

Purpose: We report an experiment to study the neural basis of regret and rejoice. An individual feels *regret* when he makes a choice that results in an outcome worse than would have occurred had he made an alternative choice. Similarly, a feeling of *rejoice* occurs when the option chosen yields a more favorable outcome than an alternative decision would have. Although the feelings of regret and rejoice are part of the human experience, their roles in shaping decisions have been widely debated. Do agents hedge their decisions prospectively, anticipating regret and rejoice and taking these potential emotions into account? In regret theory, regret and rejoice have been hypothesized to be components that enter the evaluation of the utility of a lottery (Bell 1982, 1983; Loomes and Sugden 1982, 1987; Gilovich et al, 1998) and future regret and rejoice are taken into account when an individual makes decisions. Regret theory has been invoked to explain seemingly suboptimal decision making in many domains, such as healthcare, insurance purchases, and financial investments.

Methods: To explore the neurobiology of regret and rejoice, we used fMRI to investigate the neural bases of regret and rejoice with a non-monetary medium. Incentives were created using painful outcomes in the form of mild electrical shocks to the foot and the possibility of avoiding the shocks. In each of a sequence of trials, participants were required to select one of three alternatives, when either 0, 1, 2, or 3 of the alternatives yielded a shock, depending on the trial. For our experimental design, regret theory predicts that the level of regret or rejoice associated with a particular outcome that an individual experiences depends on the prior relative likelihood of the eventual outcome. For example, winning (achieving a relatively positive outcome) from betting on a longshot, even if the outcome is the same, evokes more rejoice than winning a relatively likely prospect. Thus, we hypothesized that the neural response to a painful outcome would also reflect the degree of regret as measured by the prior probability of the outcome, with the level of regret greater, the less likely the outcome was. Similarly, when an individual avoids a potential shock, he would experience a degree of rejoice that correlates negatively with the prior probability he had of receiving the shock.

Results: Our results suggest that activation of a cortical network, consisting of the medial orbitofrontal cortex, left superior frontal cortex, right angular gyrus, and left thalamus, correlates with the degree of regret. A different network, including the rostral anterior cingulate, left hippocampus, left ventral striatum, and brainstem/midbrain exhibited activation levels correlated with the degree of rejoice. The right inferior orbitofrontal cortex, pre-supplementary motor area, anterior cingulate, and posterior cingulate showed similar patterns of activation with both regret and rejoice, suggesting that these regions may register surprise from the realization of relatively unlikely events.

Conclusion: Our results show the neurobiological activation patterns associated with the experience of regret and rejoice and that distinct, but overlapping networks are involved in the two experiences.

Title: Why is the parietal cortex involved in economic decision making?

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Abstract text (fill no more than this page)

Neuroimaging research is widely taken to support the traditional view of the prisoner's dilemma task, which depicts economic cooperation as relying on executive functioning and social cognition. This view, however, cannot account for the fact that the parietal lobe actually shows greater activation than brain regions typically associated with executive functioning and social cognition. We argue that this parietal activation stems from the numerical demands of the prisoner's dilemma task. Specifically, economic reasoning typically involves brain regions that are heavily involved in numerical cognition such as numeric comparisons, approximation and counting. To examine whether this link between numeric representation and parietal activation affects cooperation in the prisoner's dilemma, we manipulated the numerical values in payoff matrices of subjects participating in the dilemma while holding the monetary values constant (e.g., \$1 versus 100 cents). Further, we made the matrices either easy to discriminate conceptually (e.g. single digit integers) or difficult to discriminate conceptually (e.g. extremely large integers or decimals) by manipulating the values in accordance with predictions of Weber's law, a psychophysical function that describes the discriminability of numerical magnitudes. When the numbers in the payoff matrices were easy to discriminate, subjects rarely cooperated; however, when numbers were difficult to discriminate (e.g. large integers or decimals), subjects cooperated much more frequently. Indeed, when the conventional index of the temptation to defect was adjusted according to the predictions of Weber's law, our adjusted formula accounted for 97% of variance in observed cooperation rates whereas the traditional formula accounted for less than 1% of variance. We argue that these results show the strong influence of numerical reasoning on economic cooperation and that they explain why parietal regions devoted to numerical processing also process economic information.

Title: fMRI in Monkeys and Humans engaged in a foraging task.

Authors: G. S. Corrado*, L. P. Sugrue*, J. R. Brown, N. K. Logothetis, W. T. Newsome
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Abstract text (fill no more than this page)

A number of recent studies, in our lab and others, have made significant inroads in elucidating the neural mechanisms of value-based decision making. Some of these studies focus on electrophysiological recordings in monkeys working for juice rewards, while others have used functional magnetic resonance imaging (fMRI) in humans working for monetary rewards. In an effort to bridge the gap between these two branches of the literature, we present a single fMRI study in which both species forage for their preferred reward type in the same task. The ultimate goal of this endeavor is to compare results across species and across reward modalities but within a technique (fMRI), and also to facilitate synergy between techniques (fMRI and electrophysiology) within a species.

Monkeys and humans foraged on red and green visual icons that represented two competing reward sources. At any time only one of these reward sources was presented to the subject, paired with an abstract "switch" icon whose selection changed the reward source presented on the subsequent trial (referred to as changeover-key procedure). Each reward source was independently baited on a variable interval reward schedule with baiting probabilities that changed unpredictably over time. This dynamic element forced the subject to maintain an internal representation of the value of the reward sources in order to harvest rewards efficiently. The only material difference between the tasks used with the two species was the form of the rewards: juice rewards for monkeys, monetary rewards for human. Consistent with our previous work, both species reported their choices with eye movements to the desired icon.

Monkey imaging data were acquired using a purpose built vertical bore 7T magnet, while the human data were gathered in a standard horizontal bore 3T magnet. Identical and common practice techniques were used to analyze both sets of data. We report on the networks of brain areas recruited by each of several task-relevant events including option selection, reward delivery, and local reward rate. Where possible, we make direct comparisons between results in the two species. We find that the overall patterns of BOLD activation are similar across species and reward modality, bolstering the case for animal models of human economic decision making.

Title: **Marketing Actions Can Modulate Neural Representations of Experienced Utility**

Authors: Hilke Plassmann*, John O'Doherty*, Baba Shiv**, and Antonio Rangel*

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Abstract text (fill no more than this page)

A basic assumption in economics is that the experienced utility (EU) from consuming a good depends only on its intrinsic properties and on the state of the consumer. Thus, the pleasure derived from consuming a soda should only depend on the molecular composition of the drink and on the level of thirst of the individual. In opposition to this view, a sizable number of marketing actions attempt to influence EU by changing properties of commodities, such as prices, that are unrelated to their intrinsic qualities or to the consumer's state. This type of influence is valuable for marketers because EU serves as a learning signal that is used by the brain to guide future choices. For example, when facing the choice between previously experienced restaurants, one would tend to avoid locales where previously meals were unsavory. This behavior is based on biological concepts which suggest that the experience of reward (e.g. sweetness of foods) and distress (e.g. food poisoning) are biologically programmed "go" or "stop" signals that impact subsequent decision-making. Contrary to the basic assumptions of economics, several studies have provided behavioral evidence that marketing actions can successfully affect EU by manipulating non-intrinsic attributes of goods. For example, it has been shown that knowledge of a beer's ingredients can affect taste preferences; that knowledge about a beverage's brand can also affect taste preferences; and that the enjoyment of a film is influenced by expectations about its quality. Even more intriguing, another study could show that changing the price at which an energy drink is sold can influence reported alertness and the ability to solve puzzles.

Despite the importance and pervasiveness of marketing actions, almost nothing is known about the neural mechanisms through which it affects the decisions made by consumers. An important exception is a study which shows that knowledge of the brand of a culturally familiar drink, such as Coke, increases activation in the hippocampus, parahippocampus, midbrain, dorsolateral prefrontal cortex, and thalamus. The authors interpret the activity as evidence for retrieval of brand information during the consumption experience.

Our work proposes a novel mechanism through which marketing actions can affect decision-making. We hypothesized that changes in the price of a product affect the neural computations associated with EU. The hypothesis is based on previous findings showing that affective expectations influence the appraisals that are made about hedonic experiences, and through this the actual quality of experiences. Consider, for example, the experience of a consumer tasting a wine for which he has information about its retail price. Since consumers' perceptions of quality are known to be increasing with price, the consumer is likely to believe that a more expensive wine is likely to taste better. The hypothesis goes beyond this by conjecturing that the higher taste expectations would lead to an actual higher EU from consuming the wine.

To investigate the impact of price on the neural computations associated with EU we scanned human subject brains ($N=20$) using fMRI while they tasted different wines and a neutral control solution, which consisted of the main ionic components of human saliva (see Fig. 1A and the supplemental online materials). We chose wine as a stimulus because it is relatively easy to administer inside the scanner using computerized pumps, it induces a pleasurable taste sensation in most subjects, and it varies widely in quality and retail price. The results we found are consistent with our hypothesis. We found that the price of the wines affected behavioral reports of taste pleasantness and, more importantly, it also modulated the neural computations of EU made in the medial orbitofrontal cortex (mOFC) and the rostral anterior cingulate cortex (rACC).

Title: The Emergence of Product Preferences: From Early Visual Processing to Preference-based Choice

Authors: Daniel C. Krawczyk 1,2, Conrad Capili 1, Anson Chu 1, Jonathan Coker 1, Cressy Wang 2, & Julian Jamison*3,4

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Abstract text (fill no more than this page)

Product preference is clearly impacted by many factors. One of the most straightforward and basic of these factors is mere exposure to an item, through visual or auditory modalities. It has been demonstrated by psychologists and marketing researchers that this occurs even with subliminal exposure times and that repetition of exposure improves liking for items or images. We tested the effects of subliminal visual exposure to packaged store-bought products both on preference (via choices) and on brain activity (via fMRI). The items were pretested on the basis of several factors related to familiarity and valence. In particular, the included items were rated to be unfamiliar, neutral in their overall preference, and neutral in the preference toward their packaging. This was done to minimize any existing biases, in order to allow the exposure itself to have the maximal possible impact on subsequent preference judgments. The experimental procedure involved two main phases, the exposure phase and the preference phase; there was a brief final phase in which subjects were told their outcomes (while still in the scanner). In the exposure phase, subjects were presented with pictures of common grocery store items (snacks, soap, candy, drinks, nuts, and chocolate) presented in their packages. The images were presented at subliminal exposure times (20ms) such that subjects could not consciously identify the products they had viewed. Each exposed item was shown in a sequence of repetitions and was masked by a common background image. In the preference phase, subjects were presented with items that they had previously been exposed to and also with new items. Their task was to rate how much they would like each item using a token system. Items given higher token ratings were selected with higher probability for the subject to actually receive after the experiment, making the ratings incentive-compatible. This behavioral data indicated that subjects indeed preferred the exposed items to the non-exposed items. Functional MRI data indicated that repeated visual exposures resulted in suppressed visual cortex activation during later exposures as compared to early exposures. This finding is consistent with the theory that repeated exposure (even at the subliminal level) results in greater fluency for an item. Furthermore, later exposures exhibited increased activation of the medial prefrontal cortex, as well as limbic areas. This implies that exposure does not alter preferences simply by interpreting fluency (encoded within the visual system) as being positive, but that repetitive exposure actively engages regions of the brain believed to be relevant to computing the individual's preference/valuation for the items -- notably in the medial prefrontal cortex. The distinction is crucial for policy implications, insofar as (e.g.) the rationale for regulating advertising to children is dependent on the fact that repeated images cause an actual alteration of the underlying preferences and not simply an increased familiarity with the item.

Title: Delay discounting based on activation in the ventral striatum

Authors: John R. Monterosso, PhD2; George W. Ainslie, MD1; Edythe D. London, PhD2

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Abstract text (fill no more than this page)

One way impulsivity has been operationalized is as the tendency to devalue reward as a function of delay ("delay discounting"). In humans, individual or group level of delay discounting is inferred from expressed preferences for alternatives that differ in amount and immediacy. A participant's preferences may not directly reflect discounted value, however, since they may also reflect influences of mechanisms of self-control (e.g., the increased appeal of an alternative that is viewed as being the smart choice). The goal of the present study was to evaluate delay discounting without relying on preference, by inferring reward from change in activity within the ventral striatum when a research participant won rewards in a test situation. Method: Eight smokers, abstinent for 12 h, performed a card task in conjunction with functional magnetic resonance imaging (fMRI). At the onset of each trial in the task, the participants were informed of the possible reward. The task was performed on two separate occasions; during one session, the reward on each trial was either 25 or 50 cents, to be received either immediately after the task or in 1 week; and during the other session, the reward on each trial was either ½ or 1 full drag of cigarette smoke to be received either immediately after the task or in the midst of a similar 12-hour abstinent session 1 week. For comparison purposes, participants also completed a choice-based measure of delay discounting in each reward domain as well. Preliminary results: Significant activation was observed on winning trials relative to rest in the ventral striatum (VS), as well as in clusters in the prefrontal and parietal cortices. Region of interest analysis of the VS indicated that activation was present with both delayed and immediate rewards, but was significantly greater during winning trials in which the amounts were larger, and in trials in which the reward was immediate. Ongoing analyses will examine the relationship between these data and delay discounting based on participants expressed preferences. Conclusion: These preliminary results support the feasibility of using fMRI signal change in the VS to infer level of delay discounting.

Sunday, September 30, 2007

7:30 – 8:30 am

Continental Breakfast

Trust and Cooperation

8:30 – 9:00 am

Tania Singer

Empathic brain responses, prosocial
behaviour and effects of oxytocin

Tania Singer

9:05 – 9:35 am

Ernst Fehr

Testosterone as a license to
unfairness

Eisenegger Christoph, Snazzi
Romana, Naef Michael, Heinrichs
Markus, Ernst Fehr

9:40 – 10:10 am

Griet Emonds

Comparing the neural basis of
mixed-motive versus coordination
games

G. Emonds, C. Declerck, C.
Boone, P. Parizel, E. Vandervliet

10:15 – 10:45 am

Wouter Van den Bos

Development of cooperation and
competition: changes in brain
mechanisms underlying social
interaction

van den Bos, W., van Dijk, E.,
Westenberg, P.M., Crone, E. A.

11:00 am

Checkout

Title: Empathic Brain Responses, Prosocial Behaviour and Effects of Oxytocin

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Abstract text (fill no more than this page)

In the last four years, neuroscientific investigations have shed light on the mechanisms underlying our ability to empathize, that is, to share and understand feelings of others. The present study had two aims, (a) to explore possible effects of oxytocin on empathic brain responses and (b) to clarify the link between individual differences in empathic brain responses to others' pain and prosocial behaviour. We used two markers of social behaviour employed in social psychology and economics to assess (a) the propensity to reciprocate by cooperation (Conditional Co-operators) or defect (Egoists) in trust games and (b) types of social preferences (Individualistic or Prosocial). Empathic brain responses were assessed using a classic pain empathy paradigm in which subjects are scanned while they either receive painful stimulation themselves or watch their partners suffering pain. As in previous empathy for pain studies individual differences in empathic brain responses were observed in interoceptive cortex (anterior insula) and these brain responses correlated with subjective measures of unpleasantness. In contrast to our expectations, however, empathic brain responses were not significantly associated with measures of prosocial behaviour. Egoists and cooperators differed only in the self condition, but not in the other condition. Thus, egoists and individualistic types, as compared to cooperators and prosocial types, showed stronger amygdala responses towards expected pain in Self. As to be expected from previous studies, these amygdala responses were diminished when oxytocin was administered. This suggests that the fear response to aversive events is greater in egoists than in cooperators and that this can be reduced by oxytocin. Future research will have to develop alternative measures to assess real helping behaviour and further explore the link between egoistic types, trust, and amygdala-mediated fear responses.

Title: Testosteron as a licence to unfairness

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TESTOSTERONE AS A LICENCE TO UNFAIRNESS

Testosterone is in public opinion perhaps the best known hormone outside of professional medicine and biology. It is believed to be associated with aggression, dominance, status seeking, and masculinity. While many studies exist assessing the correlation between testosterone and behavioral events, very little is known about the causal effects of testosterone on human behavior. We therefore examined the impact of testosterone on bargaining behavior in a double blind placebo-controlled ultimatum game experiment. We find that subjects who believed that they received testosterone made significantly more unfair offers than subjects who believed to have received the placebo. Contrasting with this belief-effect, subjects who actually received testosterone made significantly fairer offers. Thus, it seems that popular beliefs about testosterone are taken as an excuse for unfair behavior. Its actual effect on proposer behavior is, however, in line with work in biosociology that stresses the role of testosterone in non-aggressive social dominance behavior.

Title: Comparing the neural basis of mixed-motive versus coordination games

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Understanding how (non)cooperative behavior comes about in mixed motive games still puzzles researchers in many scientific disciplines. Some people readily cooperate even in one-shot mixed motive games, whereas others never cooperate. Currently, however, the motives underlying defection are not well understood: is it the temptation to exploit a cooperative alter (greed), or is it fear of being exploited that refrains people to cooperate? In contrast, coordination games such as the Stag Hunt or Assurance Game (AG) are less complex as far as motives are concerned because cooperative synergies are embedded in the game structure, making mutual cooperation the most desirable outcome for all. As a result, a minimal level of trust suffices for cooperation to occur.

To gain insight into the relative role of fear and greed in mixed motive games, we turn to neuroimaging. Specifically, we compare the neurological correlates of solving a Prisoner's Dilemma game (PD) and an AG game. In addition, we test if individual heterogeneity in value preferences can be accounted for by differences in neural patterns associated with solving mixed motive dilemmas (as suggested by Camerer & Fehr, 2006).

We conducted an fMRI study using a 1,5 Tesla MRI scanner. Twelve participants, selected on the basis of self- versus other-regarding preferences, played a series of one-shot PD and AG games in a randomized block design. Consistent with existing research, behavioral analysis shows that participants cooperate significantly more in the AG than in the PD. As far as the analysis of the neurological data is concerned, we base our hypotheses on recent neuroscience theories developed by Frith & Frith (2006). We expect that the explicit cooperative incentives inherent in the AG will lead to more top-down processing correlating with increased activity in the prefrontal cortex. Compared to the AG, the uncertainty created by the PD is expected to lead to increased activity in the anterior cingulate gyrus, while the fear component may lead to more bottom-up processing, correlating with increased activity in the amygdala. We further expect that individual heterogeneity in neural activity will be more prominent in the PD than in the AG. Amygdala activation and bottom-up processing resulting from fear are likely to be features of people with other-regarding preferences as their strong willingness to cooperate makes them vulnerable to exploitation. If, on the other hand, self-regarding preferences are characterized by greed, top-down processing initiated by the prefrontal cortex is likely to override bottom-up processing, reducing fear and associated amygdala activation.

Title: Development of Cooperation and Competition: Changes in Brain Mechanisms underlying Social Interaction.

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Developmental comparisons provide a useful way to distinguish between component processes of decision-making. Prior findings showed that the prefrontal cortex (PFC) is one of the areas still developing structurally and functionally until late adolescence (Gogtay et al. 2004). Other findings suggest that there is a network of different areas in the PFC and the limbic system is important for decisions involving cooperation and competition (McCabe et al. 2001, Rilling et al. 2002, Gallagher et al. 2002). Based on these findings we predicted developmental changes in these types of decisions. Taking into account that different areas and connections have different developmental trajectories, we suggest distinct changes for different sub-processes.

In this study, we made use of a developmentally appropriate version of the Trust Game (Gambetta, 1998; Malhotra, 2004) targeted at the different processes involved in trust decision-making in 4 age groups ranging from 9-25 years. We manipulated the levels risk for player 1 and the benefit for player 2. The results demonstrate an increase of risk-sensitivity *and* benefit-sensitivity with age, but these developmental changes have different time courses. These findings support the hypothesis that there are several processes involved in trust decisions, some of which only emerge in middle or late adolescence. Different brain areas are expected to correlate with these processes. Currently we are examining maturation of brain regions subserving development of trust.

The result of these studies can contribute to more advanced models of decision-making, by identifying and incorporating different parameters some of which undergo developmental changes.