

## 36th Meeting of the European Group of Process Tracing Studies



**June 22<sup>nd</sup>-24<sup>th</sup>**

National University of Ireland, Galway



**NUI Galway**  
OÉ Gaillimh



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The European Association for Decision Making

# Contents

<b>Preface</b>	<b>2</b>
<b>Programme</b>	<b>3</b>
<b>Abstracts</b>	<b>8</b>
Keynote talk . . . . .	8
Panel discussion . . . . .	9
Poster session . . . . .	10
Emotions and decisions . . . . .	13
Preferential choice . . . . .	15
Social dilemmas . . . . .	17
Perceptual choice . . . . .	19
Information search . . . . .	21
Process tracing methods . . . . .	23
Attention . . . . .	26
<b>Participants</b>	<b>29</b>
<b>Social events &amp; venues</b>	<b>32</b>

# Preface

Welcome to the 36th EGPROC meeting at the National University of Ireland, Galway (NUI Galway). We are delighted to continue the tradition of the European Group of Process Tracing Studies by hosting the 2017 annual gathering of researchers interested in the basic processes underlying Judgement and Decision Making.

Research on judgement and decision making has long been an area of interest for a variety of disciplines. Within psychology, process tracing technologies are the focus of a modern fully flourishing area of research. There is no doubt that every EGPROC meeting has encouraged the further advancement of process tracing studies through fruitful discussions among specialists and young scientists.

EGPROC 2017 will explore technical and conceptual issues in decision making, comparing and contrasting models of decision making and envisioning applications in various fields. This year we have a renowned keynote speaker and an exciting panel discussion with academics from diverse backgrounds ensuring a stimulating and balanced session around the neural plausibility of decision-making models. In addition, we have 23 talks scheduled across two days in a single track to facilitate collaborative interactions. This year's contributions come from different countries (Denmark, Germany, Ireland, Italy, Netherlands, Sweden, Switzerland, UK, USA) and cover a wide range of topics.

As per tradition, this year's meeting is a space for participants to present and discuss recent research and ideas in an open and relatively informal atmosphere. Process tracing approaches are technical, so the meeting aims to facilitate the transfer of best practice and "lab lore" across laboratories to support the development of the next generation of process tracing researchers. In line with this, the first day also includes a special poster session for work-in-progress. This session will enable researchers to access friendly and supportive early feedback on their process tracing studies.

The 36th EGPROC meeting was made possible thanks to the generous support of the European Association for Decision Making (EADM), as well as the intellectual participation of committed scientists and people who love sharing their expertise and knowledge.

Le gach dea-ghuí (with every good wish),

*Denis O'Hora, Arkady Zgonnikov, Avril Hand, Santiago Garcia-Guerrero*

# Programme

**Thursday, June 22nd**

**13:30-14:30 Registration**

**14:30-15:30 Keynote talk**

Eye movements and choice models

*Neil Stewart*

**15:30-16:00 Coffee break**

**16:00-17:30 Panel discussion**

Neural plausibility of decision-making models

*KongFatt Wong-Lin, Neil Stewart, Petri T. Piiroinen*

Moderator: *Denis O'Hora*

**17:30-18:30 Poster session**

The Needleman-Wunsch algorithm: Fixation sequences as an indicator of decision processes

*Martin Schoemann*

The influence of top-down and bottom-up factors on visual attention throughout the consumer decision making process

*Kerstin Gidlöf*

Drilling down on cognitive processes: using process tracing with oilwell operators

*Vincent Ybarra*

Hybrid brain-computer interface for effective communication of decisions

*KongFatt Wong-Lin*

The effects of salience on information search in decision making

*Nicole Franke*

The Pain Game: A behavioural assessment of pain-related avoidance incorporating dynamic response measures

*Santiago Garcia-Guerrero*

**19:00-21:00 “Welcome to Galway” social event @ Tribeton**

# Friday, June 23rd

## 9:30-11:00 Emotions and decisions

Fear-related decision-making and dynamic avoidance: Lessons from a first attempt at developing a paradigm

*Santiago Garcia-Guerrero*

Choosing while losing: Investigating the effect of valence and relative magnitude on the dynamical features of choice

*Avril Hand*

You win some, you lose some - Part 2. Tracking how emotions (not) evolve

*Michael Schulte-Mecklenbeck*

## 11:00-11:30 Coffee break

## 11:30-13:00 Preferential choice

Walking dynamics of intertemporal choice

*Arkady Zgonnikov*

Context dependency in the attentional drift diffusion model

*Anna Trendl*

An attractor model of delay discounting

*Stefan Scherbaum*

## 13:00-14:00 Lunch

## 14:00-16:00 Social dilemmas

Cognitive processes underlying forward induction

*Luca Polonio*

Eyes on morals: Investigating the cognitive processes underlying moral decision making via eye-tracking

*Rima-Maria Rahal*

The cost of forgetting: Understanding the link between memory and social preferences

*Minou Ghaffari*

Is cooperation indeed intuitive? Investigating the issues of noncompliance and misunderstanding

*Ozan Isler*

## **16:00-16:30 Coffee break**

## **16:30-18:00 Perceptual choice**

How decision confidence affects hand and eye movements: An experimental and computational modelling study

*Nadim Atiya*

Investigating differences in the dynamic-systems structure of auditory cognition as a function of musical training

*Naomi du Bois*

Exploring the relationship between decision confidence and response trajectories during decision making

*Denis O'Hora*

## **19:00-21:00 Conference dinner @ Il Vicolo**

# Saturday, June 24th

## 9:30-11:00 Information search

Systematicity of search index: A new measure for describing search patterns  
*Sonja Perkovic*

Early exploratory information processing predicts performance in a reasoning task  
*Joshua Zonca*

The optimal shopping problem  
*Jacob Lund Orquin*

## 11:00-11:30 Coffee break

## 11:30-13:00 Process tracing methods

Mousetrap: An integrated, open-source mouse-tracking package  
*Pascal J. Kieslich*

Advanced mouse- and hand-tracking analysis: Detecting and visualizing clusters in movement trajectories  
*Dirk U. Wulff*

Using mouse-tracking data to visualize decision landscapes  
*Andrea Aleni*

## 13:00-14:00 Lunch

## 14:00-16:00 Attention

Using eye-tracking to account for attribute non-attendance in choice experiments  
*Rodolfo M. Nayga*

The influence of centrality and surface size on visual attention and product choice  
*Nick Zuschke*

When is attention biased towards more informative attributes?  
*Tim Mullett*

Nudging Decision Makers' Attention: A Meta-Analysis  
*Erik Stoltenberg Lahm*

**16:00-16:30 Coffee break**

**16:30-18:00 Round Table Discussion: “Issues in Process Tracing Research”**

**18:00 Closing reception @ Tigh Neachtain’s**

# Abstracts

Keynote talk

Thursday 14:30

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## Eye movements and choice models

Neil Stewart

University of Warwick, UK

Choice models seek to explain how the attribute values for choice alternatives are used to choose between alternatives. The eye movements recorded during choices are often used to give insights into the choice process. In this keynote I would like to highlight three insights from our laboratory that directly address the viability of this process tracing approach.

First, the overlap in the variability in choice explained by attribute values and the variability in choice explained by eye fixations is often not that large. For example, Stewart, Hermens, and Matthews (2016) compared the variance explained by a model predicting choice from attribute values and the variance explained by a model predicting choice from fixation counts. Only about one third of the variance predicted by attribute values overlapped with the variance predicted by fixations, and vice versa. This means that, whatever the model relating attribute values to choices, be it prospect theory or otherwise, only some of this processing is being picked up in eye movements, and much of the processing being seen in the eye movements has nothing to do with how attribute values are used in prospect theory.

A second key issue is that eye movements are not necessarily telling you about the comparison processes that go on in reaching a decision. In a set of 2 x 2 strategic games (e.g., prisoner's dilemma) people make many eye movements that indicate they understand how the game works. For example, people are very likely to compare the payoffs they receive under the two possible choices their opponent can make, as if they are thinking "I get this if they cooperate, or that if they defect". On the other hand, nonsensical comparisons are more rare. There is little use in a player contrasting their outcome if they both cooperate with the other player's outcome if they both defect—too many things are changing at once. But, although these nonsensical comparisons are rarer, when they do happen, they are just as predictive of the choice people finally make. To a first approximation, all that matters is how many times the player looks at each of their alternatives. Transitions relating to seemingly uninformative comparisons are just as predictive as sensible transitions.

Finally, we explore what the implications are for a key model linking eye movements and attribute values—the attentional drift diffusion model (Krajbich, Armel, & Rangel, 2010; Krajbich & Rangel, 2011). In this model, changes in visual attention, as measured by fixations, modulate the rates of accumulation of the values of

each alternative. Evidence is accumulated more rapidly for higher value alternatives and this accumulation is boosted when the alternative is fixated. Thus, the ADDM is assuming an interaction between attribute values and visual attention. We have compared, for many types of simple choices, models which assume independent main effects of attribute values and fixations to models which also include an interaction. Typically, two independent main effects are sufficient to capture the effects of value and attention. We suggest how the ADDM might be reformulated to capture this robust result.

**Panel discussion**

**Thursday 16:00**

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### **Neural plausibility of decision-making models**

KongFatt Wong-Lin<sup>1</sup>, Neil Stewart<sup>2</sup>, Petri T. Piironen<sup>3</sup>

<sup>1</sup> Intelligent System Research Centre, Ulster University, UK

<sup>2</sup> Department of Psychology, University of Warwick, UK

<sup>3</sup> School of Mathematics, Statistics & Applied Mathematics,  
National University of Ireland, Galway

There is little doubt that complex cognition depends on the brain. However, in order for us to model human behaviour, especially the complexities of decision making, we need to make decisions about how to construct such models and whether they should be more influenced by the limitations of the neural system or by reliably observed cognitive and behavioural patterns. Of course, we would love to have a neuro-realistic model that captures every detail of human behaviour, but such a model would likely be so complicated that it would not be usable. Today's conversation will introduce two types of decision making models, the "attractor" model of KongFatt Wong-Lin and colleagues, which has been derived from known neural principles, and the decision-by-sampling model of Neil Stewart and colleagues, which takes well established cognitive patterns as its basis, and the originators of the models will discuss their thinking when designing the models. Petri Piironen will then open up a broader discussion about the hows and whys of modelling, to facilitate our discussion of these topics.

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## **The Needleman-Wunsch algorithm: Fixation sequences as an indicator of decision processes**

Martin Schoemann<sup>1</sup>, Stefan Scherbaum<sup>2</sup>, & Frank Renkewitz<sup>1</sup>

<sup>1</sup>Technische Universität Dresden, Germany

<sup>2</sup>University of Erfurt, Germany

The aim of any process tracing study is to infer cognitive processes from observable behavior. In the JDM domain, the measurement of gaze behavior is one widely used approach to accomplish this aim. Scanpath theory proposes to base the inference of cognitive processes on similarities between fixation sequences. Recent methodological developments of process tracing in JDM research advances the application of the Needleman-Wunsch algorithm (NWA) to determine such similarities. Since in JDM exist only two studies applying the NWA on gaze data, our validation study investigates whether the NWA provides a meaningful measure of similarity on which the inference to identical or different decision processes can be based. We conducted a standard risky choice paradigm in a onefactorial within subject design with three instructed decision strategies (priority heuristic, expected value, minimax). Results revealed that the NWA detects both systematic differences and commonalties in fixation sequences, and classifies those sequences into meaningful subsets from which we can assume that they are driven by the same decision process. Therefore, we have shown that the NWA provides an applicable measure of similarity between gaze pattern, that incorporates the sequential property of gaze behavior rather than ignoring it.

## **The influence of top-down and bottom-up factors on visual attention throughout the consumer decision making process**

Kerstin Gidlöf<sup>1</sup>, Marcus Nyström<sup>1</sup>, & Annika Wallin<sup>1</sup>

<sup>1</sup>Lund University, Sweden

Product packages and displays in supermarkets are tailored to catch consumers' attention. In addition to these visually salient factors such as colours, shapes and contrast, a consumer also brings with her a set of preferences related to the products and their attributes. This work in progress aims to study the relative impact of topdown and bottom-up factors on visual attention throughout the decision making process. Many previous studies, have found that the impact of bottom-up factors such as visual saliency are greatest at the beginning of the process. Is this the case also in a decision making task in the supermarket? Both decisions and visual attention are also influenced by familiarity. Is there a difference in how bottom-up and top-down

factors influence visual attention throughout the decision process between a decision maker familiar with the environment compared to a decision maker unfamiliar with the environment? The eye movements of fifty consumers were recorded in their familiar supermarket. All participants were instructed to buy a product from three different product categories during their regular shopping. These consumers were later recorded in another, unfamiliar supermarket of the same supermarket chain, again instructed to buy products from the same categories. Our first results show that both visual saliency and preferences positively influence consumers' likelihood to look at a product. We are still to reveal the timeline of the relative impact on visual attention throughout the decision making process.

## **Drilling down on cognitive processes: using process tracing with oilwell operators**

Vincent Ybarra<sup>1,2</sup>, Younas Dadmohammadi<sup>1</sup>, Saeed Salehi<sup>1</sup>, Ziho Kang<sup>1</sup>, Jinan Allan<sup>1,2</sup>, Madhuri Ramasubramanian<sup>1,2</sup>, & Edward Cokely<sup>1,2</sup>

<sup>1</sup>University of Oklahoma, USA

<sup>2</sup>National Institute of Risk and Resilience, University of Oklahoma, USA

The National Oilwell Varco (NOV) drilling simulator allows students and experts alike to participate in virtual reality offshore drilling scenarios. Housed at the University of Oklahoma, this recent technology provides valuable educational opportunities for students and professionals, but also creates unique opportunities for researchers who can investigate human factors components in these hard to observe, high risk, and complex tasks. Offshore drilling engineers are required to process complex domain specific information, communicate with other engineers, and make appropriate, risk literate decisions. Human error in these high risk situations, has the propensity to lead to great loss of life and property, both environmentally and structurally, leading to as much as billions of dollars in costs (e.g., the Deepwater Horizon disaster). Leveraging a multidisciplinary team of researchers, we have begun to look at the underlying cognitive and metacognitive strategies drilling engineers use to evaluate and understand these risks – i.e. risk literacy (see RiskLiteracy.org). This work-in-progress has our team using eye tracking, protocol analysis, and temporal occlusion paradigms to create decision tools that will reduce cognitive load, reduce human error, and provide improved educational interventions aimed at improving informed decisions in these high risk and complex scenarios.

# Hybrid brain-computer interface for effective communication of decisions

Yogesh Kumar Meena, KongFatt Wong-Lin, Hubert Cecotti, & Girijesh Prasad  
Intelligent Systems Research Centre, University of Ulster, Derry/Londonderry

Non-invasive brain-computer interface (BCI) and eye-tracking technologies open up new communication pathways for both healthy and disabled people. However, currently available systems failed to provide sufficiently high performances to be of used in wide practical applications. We proposed a novel hybrid BCI user interface, combining BCI and gaze modalities, in which the user can make sequential decisions in minimum time with fewer iterations. The proposed system is designed to include gaze and motor imagery (MI) signals such that choice target selection can be achieved with the same interface layouts for 3 different modes of use: (i) an eye-tracker; (ii) MI signals; and (iii) a portable eye-tracker combined with MI signals. Performance is evaluated by the number of commands executed and the time to complete the task. We show that the average activity index for MI signals is significantly reduced ( $\sim 45\%$ ) with our proposed hybrid BCI layout. This study provides a proof-of-concept for designing a multimodal graphical user interface without altering the positions of the command objects for different modalities. The outcomes have implications in various applications including psychological and clinical studies.

## The effects of salience on information search in decision making

Nicole Franke<sup>1</sup>, Marc Jekel<sup>1</sup>, Andreas Glöckner<sup>1</sup>, & Arndt Bröder<sup>2</sup>

<sup>1</sup>FernUniversität in Hagen, Germany

<sup>2</sup>Universität Mannheim, Germany

Most models of decision making assume that the direction of information search is independent of the valence of available cue values. In conflict with this assumption, recent studies have demonstrated an attraction search effect in that information search is directed towards the more attractive option based on already available information in a decision situation. Using a hypothetical stock market game, we investigate whether perceptual salience moderates the size of the attraction search effect. Specifically, we expect the attraction search effect to increase when concealed cues belonging to the more attractive option are made more perceptually salient (direct effect) and also if a cue speaking for the favored option is highlighted (indirect effect). Confirmation of these hypotheses would motivate an extension of the Parallel Constraint Satisfaction model for Decision Making and Search (PCS-DM+S) to capture bottom-up factors like visual salience.

# **The Pain Game: A behavioural assessment of pain-related avoidance incorporating dynamic response measures**

Caoimhe Moran, Santiago Garcia-Guerrero, & Denis O’Hora  
School of Psychology, National University of Ireland, Galway

The primary goal of this study was to develop a novel experimental paradigm to assess fear-related avoidance as a measure of subjective fear. Individuals with phobic disorders tend to avoid fear-relevant stimuli despite this often resulting in the loss of positive rewards. While some studies have addressed the costs of such avoidance few have used these costs as a measure of subjective fear. In this study 31 undergraduate students completed a novel decision-making paradigm to investigate the extent to which fearful individuals are willing to forgo positive rewards to avoid an aversive stimulus (i.e. an electric shock). The task took the form of a card game; in one condition the shock stimulus was 30% contingent on the higher paying deck while in the other condition the shock stimulus was 70% contingent on the higher paying deck. Avoidance behaviour was highly correlated across conditions indicating that shock probabilities had little effect on avoidance. Participants high on the behavioural inhibition scale demonstrated significantly more avoidance behaviour and this had a considerable cost. Response dynamics revealed less efficient movement responses (i.e. increased response time) in high fear participants as compared to low fear participants when choosing the aversive/threat deck. A significant effect of condition (i.e. low probability condition (LPC) and high probability condition (HPC)) on the spatial characteristics of mouse trajectories was found for high fear participants only for threat deck choices.

**Emotions and decisions**

**Friday 9:30**

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## **Fear-related decision-making and dynamic avoidance: Lessons from a first attempt at developing a paradigm.**

Santiago Garcia-Guerrero, Denis O’Hora, & Arkady Zgonnikov  
School of Psychology, National University of Ireland, Galway

During the last decade, there has been a rising interest in avoidance, as a distinct behavioural process from fear, and with it a need to develop new methodologies to investigate the underlying psychological processes of this behaviour (formerly, avoidance had somewhat been subordinated or considered inherent to fear processes and thus developments in this area have lagged behind by comparison). Here we present the development and first empirical test of a “decision-making approach-avoidance paradigm” (DAAP). The DAAP consists of a “card game” interface in which participants make choices between low rewards and high rewards with an emotional cost

such as contingent exposure to a threat (e.g., spider-related stimuli). The reward values are systematically manipulated across blocks, whilst response trajectories register how much people feel attracted or repelled to the threat-related choice, as an index of dynamic avoidance. In addition, the DAAP implements the concept of “willingness to pay”, from behavioural economics, to generate a subjective value on how much an individual is willing to pay to avoid their fears, thereby, providing an estimate of “fear”. Preliminary results suggests the need to improve the sensitivity of the protocol. Key strengths and weaknesses will be discussed.

## **Choosing while losing: Investigating the effect of valence and relative magnitude on the dynamical features of choice**

Avril Hand<sup>1</sup>, Denis O’Hora<sup>1</sup>, Petri T. Piironen<sup>2</sup>, & Rick Dale<sup>3</sup>

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<sup>3</sup>University of California, Merced

Previous work in our laboratory investigated the acquisition of learning choice values and the dynamics of behaviour once these values were learned, in both gain and loss decisions. Participants chose between two symbols representing High/Low, High/High, and Low/Low values in positive-valence and negative-valence conditions. As expected, trial number increased performance and negative values were learned faster and more reliably. In addition to replicating previous effects, differences in the interpretation of choices between the two best and two worst options available were treated differently under positive-valence and negative-valence conditions. A second study investigated whether the removal of the “click” requirement in a choice response would affect the accuracy and dynamics of choices. Analyses indicated that accuracy and acquisition of learning was reduced relative to previous work. Response times were shorter and differences in response dynamics across conditions were less robust than previously observed. The current study manipulated the choice requirement further by employing mouse-over choice delay times (i.e., 0.5, 1.0, 1.5 second delays). Preliminary analyses reveal differences in the acquisition of learning choice values and the dynamics of behaviour in positive-valence and negative-valence conditions. These data support an interaction between choice requirements and evaluation of gains and losses.

## You win some, you lose some - Part 2. Tracking how emotions (not) evolve

Michael Schulte-Mecklenbeck<sup>1</sup> & Susann Fiedler<sup>2</sup>

<sup>1</sup>University of Bern, Switzerland; Max Planck Institute for Human Development, Berlin

<sup>2</sup>Max Planck Institute for Research on Collective Goods, Berlin

Emotions focus our attention and help us evaluate risks (in real life as well as in artificial situations). The classification of emotions during an experiment has been done, e.g., through self-report (Mellers et al., 1997) or RAs having a miserable time coding videos. Last year we evaluated the software iMotions and showed that our replication attempts were not fruitful. This year we will present a new study (including what we learned at last EGPROC) that shows that questionnaire ratings of valence follow the Mellers' et al. results nicely, but emotions classification values from iMotions basically come out flat. In an independent study we validate two algorithms used in iMotions for classification (AFFDEX and FACET) and report results of this classification exercise.

**Preferential choice**

**Friday 11:30**

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### Walking dynamics of intertemporal choice

Arkady Zgonnikov<sup>1</sup>, Iñaki Rañó<sup>2</sup>, Denis O'Hora<sup>1</sup>, & KongFatt Wong-Lin<sup>2</sup>

<sup>1</sup>School of Psychology, National University of Ireland, Galway

<sup>2</sup>Intelligent Systems Research Centre, University of Ulster, Derry/Londonderry, UK

The notion that cognitive processes “leak” into motor output of decisions inspired much recent process-tracing research. In mouse-tracking, an increasingly popular decision-making paradigm, difficult choices lead to increased curvature of the mouse trajectories towards the unchosen option. Here we explore whether traces of a decision process can be found in its motor output in a more naturalistic setting. Our subjects performed a series of choices between a smaller reward now and a larger reward at some delay. Using Kinect camera, we recorded subjects' walking trajectories when they moved towards their preferred option displayed in one of the corners across the room. We found that deviation of subjects' trajectories from the ideal trajectory increased with delay when they preferred the “later” option, and decreased with delay in trials where the “now” option was chosen. Our results suggest that walking trajectory of a person can provide information about their ongoing thought processes.

# Context dependency in the attentional drift diffusion model

Anna Trendl, Neil Stewart, & Timothy Mullett

University of Warwick, UK

Over the past decade, sequential sampling models of choice have become increasingly popular in decision making research. The central tenet of these models is that evidence is being accumulated over the course of the choice process until a threshold is reached and a decision is made. But what, exactly, is being accumulated throughout the decision process? Within the framework of the attentional drift diffusion model, our aim was to test the relative explanatory power of an accumulation process where it is the context-dependent subjective value of the option that is being accumulated against the benchmark raw ratings case. In our experiment, we recorded people's eye movements whilst they made a choice between three pre-rated movie posters over a 100 trials. We compared three subjective value transformation rules (ranked, range position and division by the maximum value rule) against the raw ratings (normalized by the maximum value over the whole experiment). Our results suggest that for the majority of participants, the normalized raw ratings rule outperforms the other three subjective value transformation rules. We identify key trials that are diagnostic of the mechanism underlying the poor predictive power of context-dependent models of choice in this experiment.

## An attractor model of delay discounting

Stefan Scherbaum<sup>1</sup>, Maja Dshemuchadse<sup>2</sup>, Martin Schoemann<sup>1</sup>, & Ulrike Senftleben<sup>1</sup>

<sup>1</sup>Junior professorship for Research Methods and Computational Cognitive Modelling, Technische Universität Dresden, Germany

<sup>2</sup> Faculty of Social Sciences, Hochschule Zittau-Görlitz, Germany

Many everyday choices involve options that pose a conflict between immediate, but small gains, and delayed, but larger or more beneficial gains. This conflict occurs on many time scales. For example, one might wonder whether to enjoy the pleasures of spending your money now or to save it for pension. Or one might be seduced to take the hearty burger – that is immediately very tasty - instead of the light salad – which might be better for your figure in the long-term. While research usually focusses on identifying determinants of such intertemporal choices, the presented work will focus on how the underlying system dynamics interact on different time scales: the dynamics leading to a choice, the dynamics from decision to decision and the dynamics across several decisions. I will present an attractor model of intertemporal choice that, on the one hand, integrates into the framework of discounting models and, on the other hand, predicts behavioural patterns on different time scales. I will present process-tracing studies that provide evidence for the predicted patterns in human choice behaviour in a dynamic delay-discounting game und a dynamic version of a standard intertemporal choice task.

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## Cognitive processes underlying forward induction

Luca Polonio<sup>1</sup> & Aldo Rustichini<sup>2</sup>

<sup>1</sup> Center for mind and Brain Sciences, University of Trento, Italy

<sup>2</sup>Department of Economics, University of Minnesota, USA

The principle of Forward Induction (FI) as game theoretic solution concept is that a player may be able to infer information about the intended action of the counterpart by considering the actions taken in earlier stages of a game. Our objective is to test whether, and for which subjects, the predictions of FI are supported. We recorded eye movements of 105 participants playing 96 games with different equilibrium structures. Then, we performed mixture models cluster analysis to group participants according to their patterns of visual analysis. Cluster analysis identified 4 patterns: players in cluster 1 were *focused on their own payoffs* and best responded against the uniform probability belief over the opponent's actions. Players in cluster 2 and 3 were *focused on the last stage of the game* and were able to detect equilibrium in games with unique equilibria but not to apply FI. Players in cluster 4 exhibited *distributed attention* and were able to apply FI. We show that considering the actions taken in earlier stages of the game is necessary and sufficient for FI thinking. Moreover, players who ignored past moves failed in applying FI, although a substantial fraction of them was still able to play strategically in games with unique equilibria.

## Eyes on morals: Investigating the cognitive processes underlying moral decision making via eye-tracking

Rima-Maria Rahal, Leonard Hoef, & Susann Fiedler

Max Planck Institute for Research on Collective Goods, Germany

How are moral decisions such as whether to sacrifice the life of one to rescue the lives of many others formed? The Dual Process Theory (Greene, 2001) proposes that decisions driven by utilitarian vs. deontological moral principles are preferentially supported by deliberate vs. intuitive processes. Here, we take a cognitive processing approach to this question, investigating visual attention via eye-tracking. Building on several pilot studies using trolley-type dilemma vignettes, we use a third-party dictator game with a non-hypothetical moral good (earnings obtained in a real-effort task), which decision makers can reallocate from the owner to a group of others, increasing the overall amount paid to participants. We expect differences in processing effort between chronically deontological and utilitarian decision makers, where deontologists should show faster decision times and fewer fixations. Moreover, we expect differences in decision makers' locus of attention, such that deontologists will direct more attention to information related to taking earnings away from their owner,

whereas utilitarians would pay more attention to the outcomes achieved with each action. Additionally, we study attention allocation over the course of the decision, and decision conflict between the two options via drift rates. Implications for the theoretical debate in moral psychology are discussed.

## **The cost of forgetting: Understanding the link between memory and social preferences**

Minou Ghaffari<sup>1,2</sup>, Susann Fiedler<sup>2</sup>, & Bettina von Helversen<sup>2</sup>

<sup>1</sup>Max Planck Institute for Research on Collective Goods, Germany

<sup>2</sup>University of Zurich, Switzerland

Memory has been proposed to be one of the crucial cognitive capacities required for successful cooperation in social dilemmas. Past studies give an indication that differences in memory are due to person-specific characteristics. Yet, little is known about the underlying drivers that explain these differences. We aim to investigate whether individuals' memory for social interaction partners is related to their underlying social preferences. Further, we identify potential drivers of the effect by analyzing encoding and retrieval processes. Using eye-tracking, we recorded participants' gaze behavior during the observation of other players' previous choices in decomposed games. Subsequently, participants were asked to choose which players to interact with in a sequential dictator game and later had to recall the behavior of each observed player. We used a measure for individuals' social preferences (social value orientation) to predict participants' memory performance and their attention allocation during observation. The results indicate that there are systematic differences in memory for previous players' behavior and encoding of information depending on individuals' social value orientation. These findings suggest that memory differences in social dilemmas are driven by differences in attention allocation during encoding.

# Is cooperation indeed intuitive? Investigating the issues of noncompliance and misunderstanding

Ozan Isler<sup>1</sup>, John Maule<sup>2</sup>, & Chris Starmer<sup>1</sup>

<sup>1</sup>University of Nottingham School of Economics, UK

<sup>2</sup>Leeds University Business School, UK

Inducing intuitive or reflective thinking in a public good game (e.g., via time pressure vs. delay), Rand, Greene & Novak (2012) found cooperation to decrease with reflection and interpreted this as “intuitive cooperation” (IC). The last five years saw numerous attempts to replicate this finding. However, two currently unresolved issues cast serious doubt on the interpretation of accumulated evidence as IC. First, noncompliance with time-limits remains significantly high. This issue is crucial because the literature provides evidence of IC only when noncompliant participants are excluded. We present a large-scale study that overcomes this problem by incentivising compliance. Second, misunderstanding of the public good game is suspected of confounding tests of IC, which we address in two ways: First, we provide a novel method to correct for possible mismeasurement of asymmetries in understanding by randomly assigning time-limits on understanding questions. Second, we compare understanding in the widely-used instructions of Rand et al (2012) to two pedagogically motivated instructional “supplements”. Our study resolves the issue of noncompliance, shows that misunderstanding does not confound tests of IC, and presents the first evidence of IC in the public good game that is free of compliance problems and independent of any involvement by Rand.

Perceptual choice

Friday 16:30

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## How decision confidence affects hand and eye movements: An experimental and computational modelling study

Nadim Atiya<sup>1</sup>, Arkady Zgonnikov<sup>2</sup>, Petri T. Piiroinen<sup>3</sup>,  
Denis O’Hora<sup>2</sup>, & KongFatt WongLin<sup>2</sup>

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Decision-making has been linked to the accumulation of evidence over time and is often accompanied with decision confidence, in which lower decision confidence more likely leads to change of mind. Various computational models of decision-making with confidence have been suggested. But they are either in abstract form or do not

reconcile well with recent experimental data. Further, little is known regarding how decision confidence affects the movements of eye and hand when reporting choices. In this work, we proposed a novel experimental task that revealed how hand and saccadic eye movements reflect the underlying decision dynamics and confidence. Specifically, the participants were instructed to discriminate the coherent motion direction of standard random dot kinematogram and report their decisions using hand (computer mouse) movement towards one of two choice targets while gaze was allowed to move freely. Choice accuracy and movement trajectories were recorded. Interestingly, during change-of-mind trials, hand movements preceded eye movements. We then developed a computational neural circuit model of decision-making that consists of multiple interacting brain regions while encoding decision uncertainty. Our model could mechanistically account for choice accuracy and hand and eye trajectories from the experimental data, including change-of-mind trials.

## **Investigating differences in the dynamic-systems structure of auditory cognition as a function of musical training**

Naomi du Bois<sup>1,2</sup> & Mark A. Elliott<sup>1</sup>

<sup>1</sup>School of Psychology, National University of Ireland, Galway

<sup>2</sup>University of Ulster, Magee Campus, Northern Ireland

A magnetoencephalographic (MEG) investigation was carried out on an adult sample of musicians and control group with no musical experience, using an auditory priming paradigm designed by Aksentijevic, Barber, and Elliott (2011). This paradigm employed stimulus entrainment to evoke an auditory gamma-band response (aGBR, i.e. an oscillatory response in the range 30-70 Hz) that is phase locked to the stimulus. Frequencies in this range have been demonstrated to facilitate a response to a deviant stimulus (inharmonic) depending on their relationship in phase with a slower theta rhythm. Neuroscientific research has demonstrated that syntactically irregular chords elicit event related potentials (ERPs) with negative polarity and peak latencies of around 150-350ms post stimulus onset. The focus of the time frequency and source analyses is on the effect of priming on these auditory responses as a result of musical experience. Of particular interest are the early right anterior negativity (ERAN) and the right anterior temporal negativity (RATN) responses, all passively evoked responses to deviant stimuli. Also of interest is Brodmann area (BA) 47, implicated in temporal coherence — the processing of events as they evolve over time, and recently associated with comparing musical phrases.

# Exploring the relationship between decision confidence and response trajectories during decision making

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Decision accuracy and confidence are typically related; when one is more likely to be correct, one is also likely more confident. Opinions differ as to whether this is because confidence is gleaned directly from the decision process, or because the same information that influences the decision process also influences a parallel metacognitive process. Response trajectories are influenced by decision processes and so may provide important source of evidence in this debate. In the current experiment, participants completed a series of 528 perceptual decisions, choosing the dominant horizontal direction of random dot kinematograms that varied in coherence. Following the choice, participants were required to gamble a number of points from 10 to 50 on their choice, winning the amount if they chose correctly and losing the same amount if incorrect. These gambles constituted a measure of confidence in each decision. Eye and hand movement were recorded during decisions. Participants whose accuracy increased as coherence increased also demonstrated increased gambles and reduced response times. The implications of the findings for current theories of decision confidence will be discussed.

Information search

Saturday 9:30

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## Systematicity of search index: A new measure for describing search patterns

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Leeds University Business School, UK

We propose a new measure for explaining information search and compare it to the search index (SI, Payne, 1976), the most commonly used measure for exploring the pattern of search in process-tracing studies. The systematicity of search index (SSI) explores the pattern of search in terms of systematicity or the proportion of non-random search, i.e. search that is compensatory (alternative-wise) or noncompensatory (attribute-wise) corrected for chance. The SI, on the other hand, shows the proportion of compensatory and noncompensatory search ignoring random search. We expect that the SSI will be higher in environments where information is visually organized compared to environments where it is disorganized. We test the SSI in a

discrete choice experiment with four within-subjects conditions (compensatory, non-compensatory, matrix, and random matrix visual grouping) using eye tracking technology. The results show a higher SSI in the matrix compared to the random matrix condition. The SI, however, is close to zero in both conditions. The compensatory and noncompensatory conditions show similar SSI, but differ on SI. Our experiment shows that the SSI is useful for calculating the amount of systematic search patterns in process-tracing studies and can shed light on processes not captured by the SI.

## **Early exploratory information processing predicts performance in a reasoning task**

Joshua Zonca<sup>1</sup>, Luca Polonio<sup>1</sup>, & Giorgio Coricelli<sup>1,2</sup>

<sup>1</sup>Center for Mind and Brain Sciences, University of Trento, Italy

<sup>2</sup>Departments of Economics, University of Southern California, USA.

In problem-solving and decision-making, agents need to form an efficient representation of the relational structure of the current environment. Although extensive evidence showed a general relationship between performance in complex tasks and cognitive abilities, few studies directly investigated the cognitive mechanisms modulating information representation in complex decision contexts. We recorded eye movements of 50 participants while performing a novel reasoning task designed to target relational information processing. Using individual eye-data, we identified early endogenous exploratory phases in which we could extract the visual search patterns used by participants to build relational representations. Furthermore, we collected individual measures of fluid intelligence, working memory and cognitive reflection. Based on patterns of information acquisition observed in early exploratory stages, we individuated two types of behaviour that highly predicted performance in the task: integrated and static information search. Interestingly, neither fluid intelligence nor working memory modulated the type of visual analysis employed: rather, sophistication in information processing was explained by cognitive reflection level. The current results establish a novel link between cognitive reflection and exploratory information search that can predict success in complex decision-making. Importantly, the present findings draw attention on the importance of eliciting problem representation skills besides teaching resolution procedures in educational contexts.

# The optimal shopping problem

Jacob Lund Orquin<sup>1</sup>, Sonja Perkovic<sup>2</sup>, Martin P. Bagger<sup>1</sup>, & Peter M. Todd<sup>3</sup>

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How much should we search to be efficient shoppers? Search too little and you do not find an adequate product, search too much and you waste time. We derive an optimal shopping model (OSM) that maximizes the ratio of product quality gained through search to search effort. The OSM shows that shoppers must search marginally more when the set of options ( $S$ ) is larger, and when the time to begin the search ( $t$ ) is longer. We test the assumptions and predictions of the OSM in five eye tracking studies. In Study 1, we show that visual search is random as assumed by the OSM. In Study 2, 3, and 4 we show that shoppers search marginally more options when  $S$  and  $t$  increase, as predicted by the OSM. In Study 5, we meta-analyze eye tracking studies conducted in real world environments and find that shoppers search marginally more when  $S$  is larger. Our findings suggest that shoppers are not optimal, searching too few options under time pressure and too many when not under time pressure. While not optimal, shoppers are, however, consistent with the predicted directions of the OSM, searching marginally more options when  $S$  and  $t$  increase.

Process tracing methods

Saturday 11:30

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## Mousetrap: An integrated, open-source mouse-tracking package

Pascal J. Kieslich<sup>1</sup>, Felix Henninger<sup>1,2</sup>, Dirk U. Wulff<sup>3,4</sup>, Jonas M. B. Haslbeck<sup>5</sup>, & Michael Schulte-Mecklenbeck<sup>4,6</sup>

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<sup>6</sup>University of Bern, Switzerland

Mouse-tracking – the analysis of mouse movements in computerized experiments – is becoming increasingly popular in the cognitive sciences. Mouse movements are taken as an indicator of commitment to or conflict between choice options during the decision process. Using mousetracking, researchers have gained insight into the temporal development of cognitive processes across a growing number of psychological domains. In the current contribution, we present software that offers users easy

and convenient means of recording and analyzing mousemovements in their experiments. First, we introduce and demonstrate the mousetrap plugin that adds mouse-tracking to OpenSesame, a popular general-purpose graphical experiment builder. It allows for the creation of mouse-tracking studies through a graphical interface, without requiring programming skills. Thus, researchers can benefit from the core features of a validated software package and the many extensions available for it (e.g., the integration with auxiliary hardware such as eye-tracking, or the support of interactive experiments). Second, we present the mousetrap library for the statistical programming language R. This library can import mousetracking data from a variety of sources. It offers functions for preprocessing, analyzing, and visualizing mouse movements, and calculates a variety of established measures for curvature, complexity, velocity, and acceleration. Besides, the library can easily be extended to incorporate more complex analysis and visualization approaches, and potential future extensions will be discussed. All software is cross-platform, open-source and available free of charge from:

<https://github.com/pascalkieslich/mousetrap-os>

<http://pascalkieslich.github.io/mousetrap/>.

## **Advanced mouse- and hand-tracking analysis: Detecting and visualizing clusters in movement trajectories**

Dirk U. Wulff<sup>1,2</sup>, Jonas M. B. Haslbeck<sup>3</sup>, Pascal J. Kieslich<sup>4</sup>, Felix Henninger<sup>5</sup>, & Michael Schulte-Mecklenbeck<sup>6</sup>

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Mouse-tracking and hand-tracking studies interpret curved aggregate trajectories as continuous and simultaneous competition between options. The assumptions underlying this interpretation, most importantly whether the aggregate trajectory is a proper representation of trial-level trajectories, remain however inappropriately assessed. In this project, we mainly demonstrate a novel clustering procedure for mouse-trajectories. Via the reanalysis of dozens of published datasets, we show that this tool detects substantial proportions of trajectory types that are inconsistent with the aggregate trajectory and the idea of simultaneous and continuous competitions. These results demand caution for the use of mouse-tracking as an indicator of continuous and simultaneous competition. In addition, we present several tools that help visualize and analyze mouse- and hand- tracking data.

# Using mouse-tracking data to visualize decision landscapes

Andrea Aleni<sup>1,2</sup>, Arkady Zgonnikov<sup>3</sup>, Petri T. Piiroinen<sup>4</sup>,  
Denis O'Hora<sup>3</sup>, & Mario di Bernardo<sup>2,5</sup>

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Galway

Computerized paradigms have enabled decision making researchers to gather rich data on human behaviour, including information on motor execution of a decision. Along eye tracking, one of the most used experimental tool, is the tracking of the mouse trajectories. These trajectories can reveal novel information about on-going decision processes. Here we present a new computational approach to generate decision landscape visualizations based on mouse-tracking data. Decision landscape is an analogue of energy potential field, mathematically derived from velocity of mouse movement during a decision. Visualized as a 3D surface, it provides a comprehensive overview of evolution of motor decisions. Employing the dynamical systems theory framework, we developed a new method for obtaining decision landscapes based on an arbitrary number of trajectories. Following this approach, we can, not only generate 3D illustrations of decision landscape but, also, describe each mouse trajectory by a number of interpretable parameters. This method allows us to study the decision dynamics in more details compared to conventional measures, moreover it allows to analyze the decisions comparing across different experimental conditions, and even across individuals. Given that, the proposed study might provide new insights into individual differences in dynamics of decision making. The code implementing the method is publicly available at <http://osf.io/5q364>

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## Using eye-tracking to account for attribute non-attendance in choice experiments

Ellen Van Loo, Rodolfo M. Nayga, Danny Campbell, Han-Seok Seo, & Wim Verbeke  
University of Arkansas, USA

Choice experiment (CE) is now one of the most popular methods used in preference elicitation and valuation research. This study uses eye-tracking measures to account for attribute nonattendance (ANA) in CE. ANA is an important methodological issue in CEs since it could lead to biased and misleading parameter and valuation estimates. Given that CEs are commonly used to assess attribute valuation, there is an urgent need for and considerable research interest in finding methods to account for ANA. We demonstrate various approaches to account for ANA based on definitions for detecting ignored attributes, methods to model ANA, and the number of fixation count cut-offs. Results show that some (but not all) of the attributes identified through eye-tracking measures as ‘visually ignored’ were truly ignored but we also found that the adequacy of eye-tracking as a visual ANA measure might depend on the attribute. Based on our results, we cannot conclude that eye-tracking can always adequately identify ANA. However, we identified some major challenges that can assist to further optimize the use of eye-tracking in the context of ANA in CE studies.

## The influence of centrality and surface size on visual attention and product choice

Nick Zuschke<sup>1</sup> & Bernhard Heide<sup>2</sup>

<sup>1</sup>University of Hamburg, Germany

<sup>2</sup>RheinMain University of Applied Science, Germany

The influence of centrality and surface size on visual attention and choice behavior is explored in a point of purchase environment. An eye tracking study revealed that in repeated conjoint choices both visual attention and choice of two different product sizes split according to surface size ratio. Products in the horizontal center received most visual attention and increased choice likelihood. Besides preference for center positions, left most position increased choice likelihood. Gaze likelihood curves show: Initially visual attention was rather directed to center positions than to right most position (central fixation bias). Additionally, there was a superordinate tendency to initially shift visual attention towards left most position (left gaze bias). Right before choice, visual attention was rather directed to center positions than to outmost positions (central gaze cascade). All three tendencies were connected to

choice providing further evidence for visual attention driven preferences. Decision importance and resulting task involvement is discussed to explain findings. When task involvement is too low, goal driven information acquisition is limited and incidental visual attention becomes more powerful. Based upon those findings a follow up study manipulating initial fixation is planned, It is assumed that under low task involvement in repeated choice products within an horizontal array on the opposite site of the initial fixation will decrease choice likelihood due to the distance and resulting lack of noting. The current study and the idea for the follow up study will be presented together.

## **When is attention biased towards more informative attributes?**

Tim Mullett, Neil Stewart, & Anna Trendl

University of Warwick, UK

The time course of attention biases is relatively well understood in decision tasks where subjects choose between simple, single attribute items, or options where all information is presented in one screen location. The largest, and most statistically robust effect is the gaze cascade (also known as the late onset bias), with subjects being significantly more likely to attend to the item that they subsequently choose during the last  $\sim 1$ s of deliberation. However, much less is known about the time course of attention in multi-attribute tasks where subjects must divide their attention between different items and between different attributes. We show that a similar late onset bias exists for attribute-wise attention. Results across a number of eye tracking studies show that attention becomes biased toward the attribute(s) identified by behavioural weighted additive model to best differentiate the items on the given trial. The best performing model is one that accounts for subjects' weighting of attributes, and the values of the items on a specific trial. Crucially for development of future models, the time course of this attribute wise bias is different to that of the item-wise bias. The attribute bias onsets earlier, and the effect disappears as the item-wise bias onsets, with the one effect replacing the other and the attribute attended in the final moments not being predictive of choice.

# **Nudging Decision Makers' Attention: A Meta-Analysis**

Erik Stoltenberg Lahm & Jacob Lund Orquin

Department of Management/MAPP, Aarhus University, Denmark

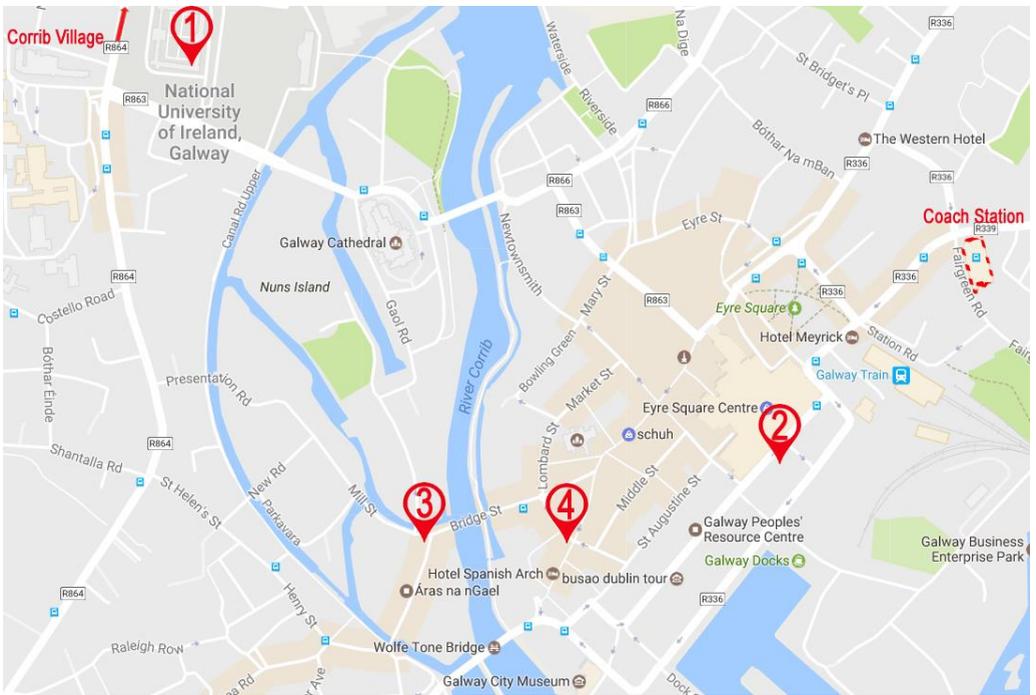
In recent years, behavioral scientists as well as policy makers have found an increasing interest in nudging. However, nudging decision-makers to attend specific elements of a message is pivotal to enhance better decisions. To gain a better understanding of attention capture, we conducted a psychometric meta-analysis on the effect of bottom-up control. We identified 44 studies related to bottom-up control and categorized it as; an object's distance to the center of the stimulus, the salience of an object, an increase in the surface size of an object, and the amount of clutter surrounding the object. We identified 17 studies related to a position effect and found that objects closer to the center of an array of objects had a moderate effect on fixation likelihood. 12 studies related to the salience of an object; objects with a higher salience had a small effect on fixation likelihood. 7 studies related to surface size; increasing an object's surface size had a moderate effect on fixation likelihood. 8 studies related to increased visual clutter showed a negative effect on fixation likelihood. Our findings imply that bottom-up control plays a guiding role in visual attention. Knowledge that is pivotal to guide decision-makers towards better decisions.

# Participants

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# Social events & venues



**(1) NUI Galway**  
University Road, H91 TK33  
Quadrangle Building  
(Aula Maxima)



**(2) Tribeton**  
1-3 Merchants Road  
091 421 600  
<http://tribeton.ie>

*Thurs 22<sup>nd</sup> 19:00*



**(3) Il Vicolo**  
The Bridgemills,  
O'Brien's Bridge  
091 530 515  
<http://ilvicolo.ie>

*Fri 23<sup>rd</sup> 19:00*



**(4) Tigh Neachtain's**  
17 Cross Street  
091 568 820  
<http://tighneachtain.com>

*Closing Reception  
Sat 24<sup>th</sup> 19:00*





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*Ollscoil na hÉirann, Gaillimh*

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