Welcome

Dear Colleague:

We are happy to welcome you to the 46th Annual Meeting of the *Society for Mathematical Psychology* being held at the University of Potsdam, Potsdam, Germany. This year's conference features keynote addresses from Felix Wichmann and Clintin Davis-Stober, the 2012 winner of the William K. Estes Early Career Award. There are also three invited symposia with a total of 26 talks, 109 contributed talks, and more than 40 posters. As a pre-conference event, there will be the meeting of Women Mathematical Psychologists on August 4th.

We would especially like to acknowledge the generous financial support of Deutsche Forschungsgemeinschaft (DFG, grant EN 471-12/1) and SensoMotoric Instruments GmbH (SMI, Teltow/Germany). Their support made an important contribution to many aspects of this year's conference, including our keynote speakers and invited symposium speakers.

Best regards,

The organizing committee: Hans Colonius, Adele Diederich, Ralf Engbert, Johannes Haack, Reinhold Kliegl, and Mark Steyvers

Program Booklet Credits

General content:	Conference Committee
Abstracts:	Their respective authors
LaTeX-code, lay-out based on an earlier version by:	Timo Kluck, Infty Advies (www.infty.nl) & MLC Inc.

Contents

General Information

Locations

The conference will be held in building 6 (Haus 6) on Campus "Griebnitzsee" of the University of Potsdam (street address: Prof.-Dr.-Helmert-Straße). All major events of the conference will take place on the ground floor; exceptions are the Women's Pre-Conference Meeting on Sunday and the SMP/JMP meetings during the lunch breaks, which will be on the first floor (please use the stairs in the lobby). The list of conference rooms in building 6 is as follows:

- **Conference Office** (Lobby Area): Registration, information desk (see map)
- **Helmholtz** (H03): Keynote talks, business meeting
- **Bayes** (H02): Symposia, parallel sessions
- **Euler** (H01): Parallel sessions
- **Fechner** (H06): Parallel sessions
- **Lobby Area**: Poster session (see map)
- **Seminar Room** (S13, 1st floor): SMP meeting, JMP editor's meeting

Welcome Reception

The Welcome Reception will be on Sunday, August 4th, in the inner courtyard of building 6, from 5:30 p.m. to 8:00 p.m. Refreshments and live music will be provided.

Conference Office

During the conference, the registration desk can be found in the conference office, building 6, lobby area. Opening hours: 8:00 a.m. to 6:00 p.m. On the opening day (Sunday, August 4th), the conference office will open at 4:00 p.m. and close at 8:00 p.m. The conference office can be reached via telephone (+49 331 977 2869).

Internet Access

Internet access will be provided via the University's WiFi network. You will find access information on a card enclosed in your conference material.

Catering, Lunch, & Coffee breaks

The Cafeteria/Mensa will be open from 8:00 a.m. to 6:00 p.m. Lunch will be offered from Monday to Wednesday between 12:30 and 1:50 p.m. Registered participants receive free conference tickets for lunch (standard menues). Refreshments and snacks will be offered during coffee breaks on Monday, Tuesday, and Wednesday in the lobby of building 6.

Conference Dinner

The conference dinner will be part of a boat trip on the Havel river on Tuesday. The charter ship will depart from the harbor "Lange Brücke", next to Potsdam Hauptbahnhof (Potsdam main train station) at 6:30 p.m. and returns at about 9:30 p.m. The number of participants is strictly limited. From the conference location (S-Bahn station "Griebnitzsee"), the train connection (S-Bahn) will take 8 minutes to Potsdam Hauptbahnhof. We strongly recommend to leave Campus Griebnitzsee at 6:00 p.m. and take the train (S1) to Potsdam Hauptbahnhof at 6:07 p.m. Please leave Potsdam Hauptbahnhof at the west exit (Ausgang West) and cross the bridge (Lange Brücke). On the left side, next to Hotel Mercure, you can find the landing.

Places to Eat

Potsdam area offers many restaurants, pubs and cafés, especially near to the S-Bahn station "Babelsberg" (one stop from Griebnitzsee, direction Potsdam Hauptbahnhof) and around the town center close to the Bassinplatz, reachable from Potsdam Hauptbahnhof via public bus or streetcar (Tram).

Avendi – Griebnitzsee: Close to the conference venue you can find hotel Avendi with an outdoor terrace right beside the water. (Rudolf-Breitscheid-Straße 190-192)

Albers – Griebnitzsee: Also close to the conference venue the restaurant Albers offers a nice atmosphere with its own beer garden. (Rudolf-Breitscheid-Straße 201)

Piazza Toscana - Griebtnitzsee: A little bit down the road you can find a great Italian restaurant called Piazza Toscana. (Rudolf-Breitscheid-Straße 177)

Gleis 6 – Babelsberg: If you are looking for an original pub we recommend Gleis 6 close to the S-Bahn station Babelsberg. (Karl-Liebknecht-Straße 4)

Café Heider – Potsdam: A traditional café of the bohemian culture in Potsdam is Café Heider in the city center. Beside its cakes and pies it offers meals and brunch. (Friedrich- Ebert-Straße 29)

Travel

Note that all registered participants will receive a free 3-day ticket for public transportation in the Berlin-Potsdam area (VBB), valid all day from Monday to Wednesday within S-Bahn, U-Bahn, busses, and streetcars (Tram).

To reach the venue before receiving the ticket with your conference material at the registration desk, participants coming from Potsdam Hauptbahnhof will need a single Potsdam-AB ticket, while participants traveling from Berlin need a single Berlin-ABC ticket. Ticket machines can be found at all train stations as well as within the streetcars (Tram), but not in the S-Bahn trains. Please remember to validate your ticket before boarding.

By Train/Public Transportation:

The urban railway (S-Bahn), station "Griebnitzsee", is located right next to the venue and can be reached by line S1 (between Potsdam Hauptbahnhof and Oranienburg/Frohnau). From Griebnitzsee, it is an 8-minute ride to Potsdam Hauptbahnhof and a 35-minute ride to Berlin Hauptbahnhof (change train at Wannsee to S7). Trains in both directions leave every 10 minutes.

Potsdam Hauptbahnhof and Schönefeld Airport are connected by the train RB22,

which leaves Potsdam about once every hour. The ride takes 40 minutes. To go to Tegel Airport take the S-Bahn S1 to Wannsee, switch to the S7 to Westkreuz, switch again to the circle line S41 to Jungfernheide and take the bus line X9 to Tegel airport. Alternatively, you can take the S7 to Charlottenburg and switch to the bus line 109 to Tegel airport. It takes about 55 minutes from Potsdam Hauptbahnhof to Tegel Airport.

Within Potsdam city you can find a comfortable bus and streetcar (Tram) system, which will take you to the main station. Train connections can be found on `http://bvg.de` or `http://bahn.de`.

By Car:

From Potsdam Main Station: Turn left on Friedrich-Engels-Straße and follow the street for aproximally 2 km. Leave the roundabout at the second exit (Schulstraße) and go straight ahead. Turn left on August-Bebel-Straße after 2 more km. The second street on the right is Prof.-Dr.-Helmert-Straße, where you will find the venue.

From Hotel Acrona: Turn left on Zeppelinstraße and go straight ahead for one km. Turn right on Breite Straße and go ahead till you can see the river. Cross the bridge "Lange Brücke" and after 500 meters turn left on Friedrich-Engels-Straße. Now follow the instructions "From Potsdam Main Station".

From Hotel Mercure: Turn left on Breite Straße and cross the bridge "Lange Brücke". After 500 meters turn left on Friedrich-Engels-Straße. Now follow the instructions "From Potsdam Main Station".

From Berlin: Take the A115 to Potsdam and exit on Potsdam Babelsberg. Continue on Nuthestraße and exit on Medienstadt/Filmpark/Wetzlarer Straße Turn right on Fritt-Zubeil- Straße and left on Wetzlarer Straße. Drive straight ahead until right in front of the railway tracks where you turn right into Prof.-Dr.-Helmert-Straße.

From Tegel airport: Take the A111 to Dresden/Magdeburg/Leipzig/Zentrum. After approximately 2 km take the A100 and about 4 km later take the A115/E51 to Leipzig/ Magdeburg/Potsdam. Now you can use the introduction above "From Berlin".

From Schönefeld Airport: Take the A113 to Dresden. At the interchange Schönefelder Kreuz stay right and follow the signs to A10/Berliner Ring to Magdeburg/Leipzig/ Potsdam. After 30 km turn right on the A115 to Flughafen Berlin-Tegel/Potsdam - Zentrum/Berlin-Zentrum/Berlin-Zehlendorf at the interchange Dreieck Nuthetal. Exit on Potsdam Babelsberg after 10 km and follow the introduction above "From Berlin".

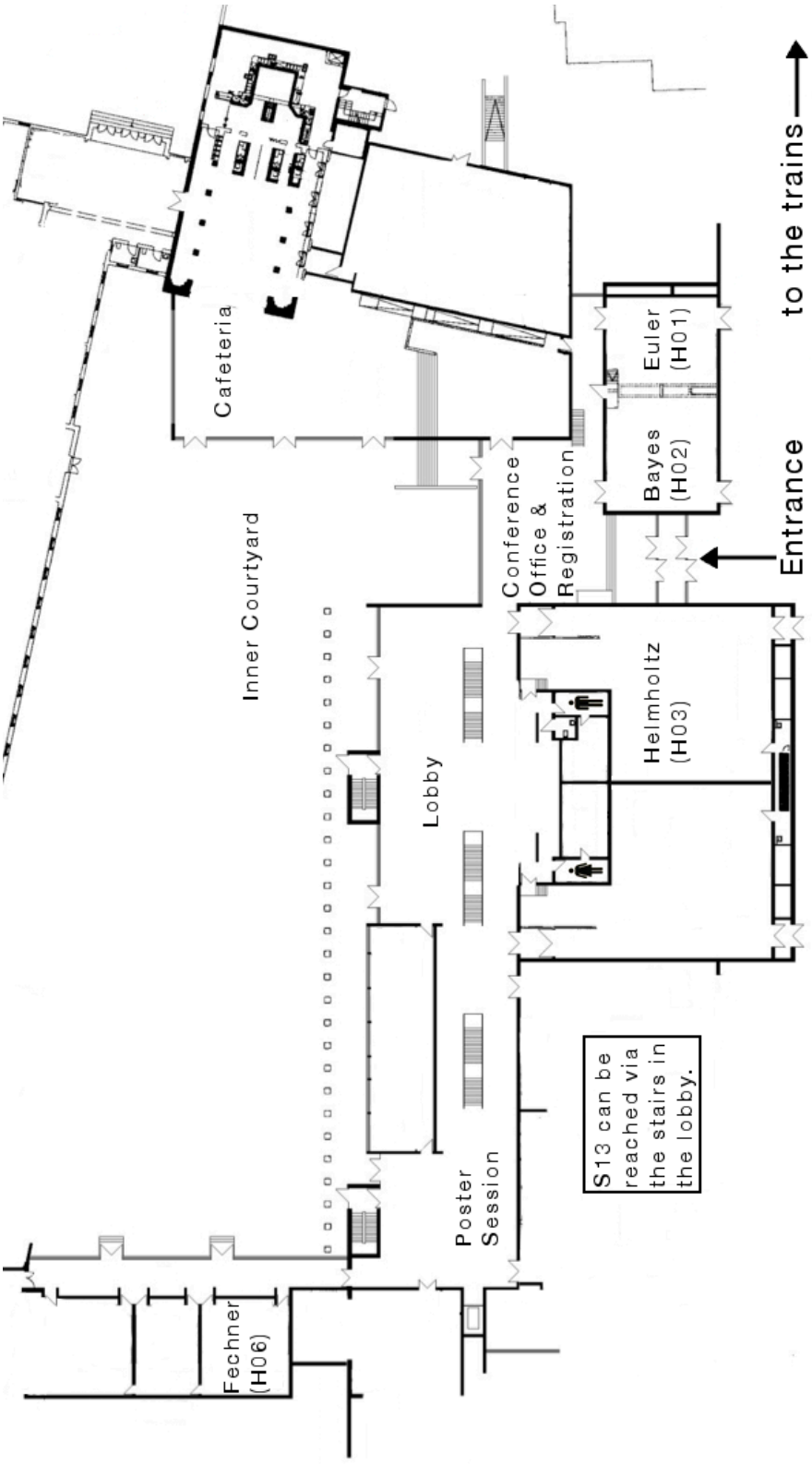
Co-located Conferences

ESLP 2013, Potsdam
July 29, 2013, to July 31, 2013
http://www.eslp-conference.org

SCSCS 2013, Berlin
3rd SCSCS Meeting on July 30th, 2013
http://perceptualdynamics.be

CogSci 2013, Berlin
July 31, 2013, to August 3, 2013
http://cognitivesciencesociety.org/conference2013/

Floor Plan for Building 6, Campus Griebnitzsee



Presentation Guidelines

Talks

There will be three parallel talk sessions in rooms Bayes, Euler and Fechner (H01, H02, and H06) on Monday, Tuesday, and Wednesday consisting of strict 20-minute slots for every talk (15 min. talk + 5 min. for discussion). It is essential to stay in time to offer everyone the opportunity to switch sessions in order to hear specific talks.

In all the rooms you will find the option to connect your own computer or tablet to the presentation equipment. In case you plan to use the local computer (Apple MAC OS-X), please give your presentation in PDF format to the technical room assistant well before the session starts.

Keynote Speakers

The invited talks by Felix Wichmann and Clintin Davis-Stober will be held on Monday and Wednesday in room Helmholtz (H03) at 9:00 a.m. and 10:30 a.m., respectively. Felix Wichmann will give a presentation on "Machine learning methods for system identification in sensory psychology" and Clintin Davis-Stober will speak on "A new perspective on non-compensatory decision-making: theoretic and empirical results."

Invited Symposia

There will be three invited symposia in room Bayes (H01). The first symposium is on Monday at 10:30 a.m. a symposium on "Mathematical Models of Eye Movements" (Chair: Ralf Engbert). After the lunch break, a "Symposium in Honor of Duncan R. Luce" will be chaired by James T. Townsend. The third symposium will be on "Joint Modeling of Behavioral and Neural Data" (Chair: Brandon M. Turner) will start on Tuesday at 8:40 a.m.

Posters

The posters will be on display from Monday 9:00 a.m. to Wednesday 3:00 p.m. The poster session will take place on Monday, from 5:40 p.m. to 7:30 p.m. in the lobby area. Please look up your poster ID in this booklet and attach your poster to the corresponding poster board. The size of the poster board is 841 mm (width) $\times$ 1189 mm (height).

Pre-Conference Meeting of Women Mathematical Psychologists

A pre-conference meeting of Women Mathematical Psychologists on "Networking and Collaboration" will be held on Sunday, August 4th, from 1 p.m. to 4 p.m. The keynote speaker will be Professor Adele Diederich, Jacobs University, Bremen, and a member of the academic network (AcademiaNet).

We welcome all (not just women) who are interested in this topic to attend. The purpose of the meeting is to promote the involvement of women in the field of mathematical psychology, and to highlight the contributions of women in mathematical psychology in order to inspire other women to pursue a career in the field.

In addition to the keynote speaker, there will be a panel discussion of relevant topics, as well as active networking activities. Panelists will include Laurie Feldman, Birte Forstmann, Michael Lee, and Amy Criss.

If you have specific topic suggestions, please send them to the symposium organizers: Pernille Hemmer, Jennifer Trueblood and Annemarie Zand Scholten. (E-mail addresses can be found in the Author Index on page 101.)

The pre-conference meeting will be held in seminar room S13 (1st floor, building 6, Campus Griebnitzsee).

Abstracts For Keynote Talks

Chair: Hans Colonius

Monday, 9:00

Helmholtz

Machine learning methods for system identification in sensory psychology. Felix A. Wichmann, *University of Tübingen, Germany*. As a prerequisite to quantitative psychophysical models of sensory processing it is necessary to know to what extent decisions in behavioral tasks depend on specific stimulus features, the perceptual cues: Given the high-dimensional input, which are the features the sensory systems base their computations on? Over the last years we have developed inverse machine learning methods for (potentially nonlinear) system identification, and have applied them to identify regions of visual saliency (Kienzle et al., 2009), to gender discrimination of human faces (Wichmann et al., 2005; Macke & Wichmann, 2010), and to the identification of auditory tones in noise (Schönfelder & Wichmann, 2012; 2013). In my talk I will concentrate on how stimulus-response data can be analyzed relying on L_1-regularized multiple logistic regression. This method prevents both over-fitting to noisy data and enforces sparse solutions. In simulations, "behavioral" data from a classical auditory tone-in-noise detection task were generated, and L_1-regularized logistic regression precisely identified observer cues from a large set of covarying, interdependent stimulus features (a setting where standard correlational and regression methods fail). In addition, the method succeeds for deterministic as well as probabilistic observers. The detailed decision rules of the simulated observers could be reconstructed from the estimated model weights, thus allowing predictions of responses on the basis of individual stimuli. Data from a real psychophysical experiment confirm the power of the proposed method.

Chair: Mark Steyvers

Wednesday, 10:30

Helmholtz

A new perspective on non-compensatory decision-making: theoretic and empirical results. Clintin P. Davis-Stober, *University of Missouri, United States of America*. Lexicographic semiorders are mathematical structures often used to model non-compensatory decision processes (e.g., Fishburn, 1991; Tversky, 1969). A key feature of such models is that a decision maker considers the attributes of choice alternatives sequentially, preferring one choice alternative over another if, and only if, a pair of attribute values differ by a fixed threshold, i.e., a semiorder structure. I present a lexicographic semiorder model of probabilistic choice that allows a decision maker to have varying preferences with the restriction that at each sampled time point the decision maker's preferences are consistent with a lexicographic semiorder.

I demonstrate how this theory can be used to disentangle the response variability of a decision maker's observed choices with the variability of his or her true preferences. When used in conjunction with existing random preference models, this theory allows for a comprehensive test of a large class of utility representations. I report the results of several new decision-making under risk experiments. We find that while traditional utility representations describe a majority of individuals, a distinct subset of decision makers consistently make choices that are best described by mixtures of lexicographic semiorders.

Abstracts For Symposium Talks

(Symposium abstracts organized by day and presentation order)

Mathematical Models of Eye Movements

Organizer: Ralf Engbert

Monday, 10:30

Bayes

Effects of microscopic eye movements on contrast sensitivity in humans and neurons. Michele Rucci, *Boston University, United States of America*, Jonathan D. Victor, *Weill Cornell Medical College, United States of America*, Xutao Kuang, *Boston University, United States of America*. The response characteristics of neurons in the early visual system are often studied in anesthetized primates, under conditions in which their eyes are paralyzed. Contrast sensitivity functions of neurons measured in these conditions deviate significantly from behavioral measurements of contrast sensitivity: psychophysical measurements peak at higher spatial frequencies and exhibit stronger low-frequency suppression than their neurophysiological counterparts. One possible basis for this discrepancy is the effect of abolishing eye movements in neurophysiological recordings. Microscopic eye movements are always present during natural fixation, and they have been shown to enhance high spatial frequency vision. Here, we examine how neuronal response properties determined in the absence of retinal image motion apply to natural viewing conditions. We describe an "equivalent filter" for retinal ganglion cells which combines measures of neural responses determined with an immobile stimulus and the statistics of human fixational eye movements. We show that consideration of fixational eye movements eliminates the discrepancy between psychophysical and neurophysiological measurements. For both P and M cells, neuronal sensitivity shifts towards higher spatial frequencies when the influence of fixational eye movements is taken into account. Our model predicts that contrast sensitivity functions measured with paralyzed eyes significantly underestimate the actual responses to high spatial frequencies present during natural viewing.

Monday, 10:50

Bayes

Bayesian estimation of the scaling parameter of fixational eye movements. Natallia Makarava, *University of Potsdam, Germany*, Mario Bettenbühl, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*, Matthias Holschneider, *University of Potsdam, Germany*. In this study we re-evaluate the estimation of the self-similarity exponent of fixational eye movements using Bayesian theory. Our analysis is based on a subsampling decom-

position, which permits an analysis of the signal up to some scale factor. We demonstrate that our approach can be applied to simulated data from mathematical models of fixational eye movements to distinguish the models' properties reliably.

Monday, 11:10

Bayes

Gaze in real-world scenarios: interaction of task and stimulus. Wolfgang Einhäuser, *Philipps-University Marburg, Germany; Center for Interdisciplinary Research (ZiF), Bielefeld, Germany*, Bernard Marius 't Hart, *Philipps-University Marburg, Germany; Physiological Genomics, Ludwig Maximilian University, Munich, Germany*. Under natural conditions gaze is a good proxy for the deployment of spatial attention. In a series of studies we investigated how such "overt attention" is deployed in natural scenes and to what extent results from the laboratory transfer to the real world.When comparing eye movements during prolonged viewing to target detection in a rapid-serial visual presentation (RSVP) task, we find that the probability to detect a target (e.g., an animal) in a rapidly presented natural scene correlates to its probability to be fixated in prolonged viewing. In addition, both measures are affected similarly by a modification of the target's luminance contrast. This result provides a link between covert attention in time and overt attention in space in the context of natural stimuli. It has been suggested that the probability of an item in a natural scene to be fixated ("salience") is related to the probability of it being named as describing the scene ("importance"). While we confirm this relation for unmodified natural scenes, we dissociate both measures by modifying the item's luminance contrast. Whereas salience is affected by the actual features of the current stimulus, importance is more closely related to the features of an object that are expected based on scene context. This cautions us that models of attention need to be tested against actual attention measures, such as fixation probability, rather than relying solely on the annotation of large-scale databases by merely asking observers, which objects they consider important or salient. Finally, we demonstrate by using a wearable eye-tracking device that data obtained in laboratory experiments on natural stimuli, have only limited predictive power for gaze allocation during free exploration in the real world. First, laboratory data in principle fails to mimic implicit tasks that are imposed on the participant by the environment to avoid a severe cost (e.g., tripping over). Second, typical data obtained in head- and body fixed setups fails to acknowledge the distinct contributions of different effectors (eye, head and body) for orienting gaze.In sum, although different measures of attention share commonalities, our findings exemplify some of the challenges that need to be met when transferring models derived from (and tested on) constrained laboratory setups to gaze allocation during activities in the truly real world.

Monday, 11:30

Bayes

Eye can read your mind: Decoding gaze fixations to reveal categorical search targets. Gregory Zelinsky, *Stony Brook University, United States of America*. Using a technique that we refer to as behavioral decoding, we demonstrate that the information available in the fixation behavior of subjects can be suffi-

cient to decode the category of their search target—essentially reading a person's mind by analyzing what they look at as they search. One group of subjects searched for teddy bear targets among random category distractors, another group searched for butterflies among the same distractors. Two SVM-based classifiers, trained to recognize teddy bears and butterflies, were then used to classify the distractors that were preferentially fixated by subjects during search as either teddy bears or butterflies based on their distances from the SVM decision boundaries. Two methods of preferential fixation were explored, the object first fixated during search and the object fixated the longest. Using the longest-fixation method, we found that the target of a person's search could be decoded perfectly when one of the distractors was rated as being visually similar to the target category. Even with completely random distractors, the target category could still be decoded for 75-80% of the subjects. The much harder task of decoding the target on individual trials (from a single object fixation) resulted in much lower classification rates, although targets were still decoded above chance. These findings have implications for the visual similarity relationships underlying search guidance and distractor rejection, and demonstrate the feasibility in using these relationships to decode a person's task or goal.

Monday, 11:50

Bayes

Point process models for eye movement data. Simon Barthelmé, *University of Geneva, Switzerland*, Hans A. Trukenbrod, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*, Felix A. Wichmann, *University of Tübingen, BCCN, and MPI for Intelligent Systems, Tübingen*. Whenever eye movements are measured, a central part of the analysis has to do with where subjects fixate, and why they fixated where they fixated. To a first approximation, a set of fixations can be viewed as a set of points in space: this implies that fixations are spatial data and that the analysis of fixation locations can be beneficially thought of as a spatial statistics problem. We will argue that thinking of fixation locations as arising from point processes is a very fruitful framework for eye movement data.We will provide a tutorial introduction to some of the main ideas of the field of spatial statistics, focusing especially on spatial Poisson processes. We will show how point processes help relate image properties to fixation locations. In particular they express quite naturally the idea that how image features predict fixations might vary from one image to another. We will review other methods of analysis used in the literature, show how they relate to point process theory, and argue that thinking in terms of point processes substantially extends the range of analyses that can be performed and clarify their interpretation.

Monday, 12:10

Bayes

Using spatial statistics of gaze patterns to model attentional selection. Ralf Engbert, *Universität Potsdam, Germany*, Hans A. Trukenbrod, *Universität Potsdam, Germany*, Simon Barthelmé, *Université de Genève, Switzerland*, Felix A. Wichmann, *Universität Tübingen, Germany*. Computational neuroscientists have developed biologically plausible models of visual attention during scene perception. In this approach,

a range of mathematical models has been proposed for the computation of saliency maps from arbitrary input images. However, results are evaluated based on first-order statistics without considering dynamical effects. Here we apply point process theory to gaze patterns to discover spatial clustering on small length scales along individual scanpaths recorded from human observers. We propose a dynamical model of attentional and saccadic selection, which is driven by static saliency maps, but implements activation dynamics for accurate prediction of spatial clustering.

Symposium in Honor of Duncan R. Luce (Part I)

Organizer: James T. Townsend

Monday, 1:50

Bayes

Duncan Luce and the Foundations of Measurement. Louis Narens, *UCI, United States of America*. Duncan Luce was one of the founders of the Modern Theory of Measurement. This lecture will review some of his important contributions to foundations of measurement from his early work on semiorders to his later work on non-additive representations, and the impact of his contributions to psychology and science.

Monday, 2:10

Bayes

Markov versus Quantum Random Walk Models of Decision Making. Jerome R. Busemeyer, *Indiana University, United States of America*, Joyce Wang, *Ohio State University*, Tim Pleskac, *Michigan State University*, Peter Kvam, *Michigan State University*. Random walk/diffusion models are normally constructed as Markov models. In particular, the popular diffusion models are Markovian. These models have been very successful in cognitive science for simultaneously fitting choice, decision time, and confidence. Quantum theory provides an alternative way to construct probabilistic and dynamic models. A few years ago, the authors developed a quantum random walk model, but our initial attempt did not fit choice and response time data as well as a corresponding Markov model. Recently Fuss and Navarro presented an alternative quantum random walk that actually fit choice and response time data slightly better than a corresponding Markov model. But slightly better fits to data probably will not shift opinions very much, and stronger qualitative evidence is required. This paper theoretically compares quantum and Markov models, and more importantly, we present ways to qualitatively distinguish quantum versus Markov models based on sequential measures of choice and confidence.

Monday, 2:30

Bayes

Positive dependence via variability. Hans Colonius, *University of Oldenburg, Germany*. Several concepts of statistical dependence, generalizing common indices like Neyman-Pearson or rank correlation, have been shown to be useful in the stochastic modeling of perceptual/cognitive processes. Here we discuss recent results on how positive dependence among random variables representing perceptual/cognitive processes can be modulated by increasing or decreasing the variability of certain sub-processes.

Monday, 2:50

Bayes

Topological Characterization of Interval and Semi-Orders. Jun Zhang, *University of Michigan, United States of America*, Yitong Sun, *University of Michigan, United States of America*. The concept of semi-order was introduced by Luce (1956) to capture the intransitive indifference relation prevalent in social and behavioral sciences. Its numerical representation manifests a threshold structure (Scott-Suppes representation) characteristic of comparative judgments in psychophysics. Later, it became known that semi-order (and its fixed-threshold representation) was a special case of the more general interval order (and its interval graph representation) as succinctly characterized by Fishburn and many others. Here, we first review how interval order induces a "nesting" relation, a partial order itself. A set with a semi-order on it is then precisely an interval-ordered set that does not contain any nesting among its elements. When nesting occurs, an interval-ordered set has two lexicographic orders, which agree on the subset of elements that do not nest one-another. Next, we investigate topologies on interval-order sets, and construct a topology (based on the notion of upper- and lower-holdings) that allows us to relate topological axiomatic separations to order relations. Specifically, under our proposed topology, two distinct elements are (i) nested iff they are T_0 but not T_1 separated; (ii) indifferent but non-nested iff they are T_1 but not T_2 separated; (iii) comparable iff they are T_2 separated. Therefore, we achieve topological characterization of pairwise relations of all points in an interval-order set in terms of their topological separability.

Monday, 3:10

Bayes

Model Mimicry of Diffusion Processes by Independent-Channels Parallel Race Models. James T. Townsend, *Indiana University Bloomington, United States of America*, Arash Khodadadi, *Indiana University Bloomington, United States of America*. In the past few decades, several sequential sampling models have been proposed that can account for the reaction time and choice probability data obtained from 2-choice decision tasks. With few exceptions, these models assume that in response to a constant stimulus, the information accumulation rate and the decision thresholds are constant within a trial. This raises the question: How do these models behave when we relax these assumptions? Specifically, can one model with time-varying threshold and/or information accumulation rate mimic the behavior of another model without temporal variation of this kind? We prove that any diffusion process with constant drift rate and two constant boundaries can be mimicked by an independent race model with time-varying boundaries. The properties of the boundaries are then investigated. In addition, extensive simulations indicate that such a constant threshold diffusion model can also be mimicked by an Ornstein-Uhlenbeck process with decreasing boundary. Finally, we see if this equivalence between models holds for all temporal shapes of a stimulus. That is, can a model with a specific boundary mimic the other model even when the stimulus is time-varying? We show that this is not the case and so time-varying stimuli constitute a potential strategy to distinguish among these models.

Monday, 3:30

Bayes

A Representation Theorem for Symmetric ROCs. Geoffrey Iverson, *University of California, Irvine, United States of America*. An ROC is symmetric if it is invariant under reflection in a mirror placed on the negative diagonal. For a given symmetric ROC there are very many signal and noise sources that generate that ROC. We show that among these multiple random variables there always exists an especially simple one in which both signal and noise values are concentrated on an interval symmetric about zero, and such that signal values are distributed as the negative of noise values. These random variables are, in general, a mixture of a continuous and an atomic variable and are constructed directly form the ROC.

Symposium in Honor of Duncan R. Luce (Part II)

Organizer: James T. Townsend

Monday, 4:20

Bayes

Psychophysics and Response Time: Our Enduring Debt to Duncan Luce. Philip L. Smith, *University of Melbourne, Australia*. Most of the fundamental issues in psychophysics and response time modeling were investigated with extraordinary depth and perspicacity by Luce during his long and distinguished career. These include: (1) the laws governing the sensory representations of stimuli and the relationship between their deterministic and stochastic parts; (2) the relationship between behavioral-level representations of stimuli and their neural substrate; (3) the role of attention in selectively processing the sensory continuum, and (4) the effects of time-varying sensory processes on perceptual decision-making. These issues have been the dominant themes of the work carried out in our laboratory in the last two decades, much of it inspired by Luce's insights. Recently, we have sought to consider all of these issues together, in the context of a model, the integrated system model, that links perception, attention, visual short-term memory, and decision-making in an integrated dynamic framework. I illustrate these themes using our recent work on visual short-term memory, capacity limitations, and decision-making, emphasizing the link to Luce's seminal contributions.

Monday, 4:40

Bayes

Luce's Theoretical and Empirical Applications of Measurement Theory: The last 15 years. Ragnar Steingrimsson, *UC Irvine/NWEA, United States of America*. The publication of Foundations of Measurements I-III (1971, 1989, 1990) became a milestone in the development of the axiomatic approach to measurement. The approached offered an avenue towards solving one of the central problems of scientific psychology, namely, how to measure the not directly observable sensation that intervenes between physical stimuli and behavioral responses. The measurement solution was to formulate necessary and sufficient testable axioms from which particular numerical representations could be derived. If the axioms were found to hold, the representations followed from mathematical logic. With time, some ap-

plications emerged in utility theory, but in psychology, the results amounted more to a "nonrevolution" (Narens & Luce, 1993). Luce (2002, 2004, 2008, 2012) formulated a Theory of Global Psychophysics, which has become the largest effort to date to build a psychological theory on the basis of axiomatic measurement theory. In its current form, the theory provides a description of (in principle) the entire domain of intensive dimensions and it has been favorably evaluated in several domains. As anticipated, the theoretical construction allows for derivation of consequences, often about existing problems, and often entirely novel ones, and much of Luce's most recent work in this area involved formulating and evaluating such predictions. In this talk, I will describe the basic components of the theory, including how measurement axioms are brought to bare on the problem at hand, and some of the numerous empirical conclusions reached over the last decade. I will conclude with an overview of the many projects that are still left to be undertaken and some of the avenues to which the theoretical approach might continue to be expanded and applied.

Monday, 5:00

Bayes

Invariant deadline models for speed-accuracy tradeoffs in choice response tasks. Dirk Vorberg, *Westfälische Wilhelms-Universität (WWU) Münster, Institut für Psychologie*. Subjects can adjust their performance speed and accuracy in choice tasks, increasing response accuracy at the cost of reduced speed, and vice versa. Different from most other models of speed-accuracy tradeoffs, deadline models (Ollman, 1966) assume that subjects control speed and accuracy by setting time limits for stimulus processing. If processing has not been completed when the deadline expires, a response is generated that may be based on partial information or pure guessing. My presentation will give a solution to the problem raised by Yellott (1971) whether one can obtain an estimate of the distribution of stimulus processing times, $S(.)$, that does not require specific assumptions about the shape of the deadline distributions, $D(.)$, and describe an experimental test of the corresponding deadline models for which the invariance might or might not hold. References: Ollman, R. T. (1966) *Psychonomic Science, 6,* 155–156; Yellott, J. I. (1971). *Journal of Mathematical Psychology, 8,* 159–199.

Monday, 5:20

Bayes

A challenge for neuroscience: How the brain can compute data fast enough to match well-known fast behavioral response times in recognizing familiar objects and processes. Patrick Suppes, *Stanford University, United States of America*. In a lecture dedicated to Duncan Luce, a focus on response times is more than appropriate. He probably wrote more about the quantitative theory of response times than any other behavioral scientists in recent times. My lecture focuses on how well can we provide a theory of the brain processes that do these fast computations.

Monday, 5:40

Bayes

Memories of My Friend. Eugene Galanter, *Columbia University, United States of America*. (read by Ragnar Steingrimsson).

Joint Modeling of Behavioral and Neural Data (Part I)

Organizer: Brandon Turner

Tuesday, 8:40

Bayes

Computational models of prediction learning: comparing decisions, reaction times, and BOLD. Nathaniel D. Daw, *New York University, United States of America*. Different observables, e.g., BOLD, reaction times, and decisions, can be unified by characterizing them as different windows on a common underlying computational process. In a growing approach to studying functions like reinforcement learning, data are assumed to be generated from a computational model (such as temporal difference learning) together with a set of observation models (such as hemodynamic convolution) that probabilistically link the variables computed in the model (such as reward prediction errors) to different modalities of data. This procedure converts an abstract computational model into a statistical generative model for data, whereupon standard inference techniques can be used to estimate model parameters, and also (less commonly) to compare or pool these estimates across modalities. I exemplify this approach with a series of functional neuroimaging studies of how humans learn to predict sequential events. Participants viewed a series of images generated according to a first-order Markov process, and had to identify each of them with a button press. We use a standard error-driven learning model to characterize the trial-by-trial formation of expectations about the image sequence, as reflected in the well-known facilitation of reaction times to more probable events. Next, we fit the same model to decisions in an interleaved choice task (whereby subjects effectively placed side bets about the likely image sequences) and to BOLD activity related to image expectation or decision variables in a number of areas across both tasks. By comparing estimated model parameters (specifically, the learning rate parameter, which controls how strongly the learned predictions are biased toward the most recent events) across all these datastreams, we are able to demonstrate evidence for two distinct learned representations of the task's predictive structure. These two learning processes are associated with distinct learning rates and anatomical substrates, and combine in different ways to produce implicit (reaction time) and explicit (choice) behavior. (Joint work with Aaron Bornstein.)

Tuesday, 9:00

Bayes

Relating neural and behavioral dynamics of decisional processes: from simple to more complicated tasks. Marieke K. van Vugt, *University of Groningen, The Netherlands*, Marijke Beulen, *University of Groningen, The Netherlands*. Model-based neuroscience is a relatively new approach to investigating the relationship between the brain and cognition. To date, it has primarily focused on relating relatively simple mathematical models such as the drift diffusion model to the brain. For example, we have previously shown that the process of evidence accumulation during a perceptual decision making task is associated with the amplitude of 4–9 Hz theta oscillations recorded with scalp EEG. We have also found that 4–9 Hz theta oscillations also correlated with the

dynamics of evidence accumulation during a recognition memory task.Yet, such simple models have limitations. For example, these evidence accumulation models do not make specific predictions about the nature of the evidence that is being accumulated, how that evidence enters the decision process, and how the output of the accumulation process is transformed into motor commands. We will show an example of how cognitive architectures such as ACT-R can be helpful in modeling these more specific processes that become increasingly relevant in more complex tasks. This model can make predictions about times at which information is being communicated between different cognitive resources, and as such, contributes a theoretical framework for interpreting patterns of coherence between oscillations in different electrodes. For example, we found that coherence between posterior and parietal electrodes in the theta band may reflect information retrieval about perceived visual stimuli.Thus, by combining knowledge from both simple models and more complicated cognitive architectures, model-based neuroscience can make important contributions to our understanding of the role of oscillatory brain activity in cognition.

Tuesday, 9:20

Bayes

Modeling Neural Dynamics and Behavioral Dynamics of Perceptual Decision Making. Thomas J. Palmeri, *Vanderbilt University, United States of America*, Braden A. Purcell, *Vanderbilt University, United States of America*, Jeffrey D. Schall, *Vanderbilt University, United States of America*, Gordon D. Logan, *Vanderbilt University, United States of America*. Mathematical psychology and systems neuroscience have converged on accumulation of evidence models as a general theoretical framework for explaining the time course of perceptual decision making. Our work usesthese models to forge connections between computational and neural levels of explanation in the context of saccade decisions by awake behaving monkeys while neural recordings were made within their frontal eye field (FEF). A family of accumulator models were tested on how well, or how poorly, they accounted for detailed patterns of observed saccade data, including response probabilities and distributions of response times, following common methods used in mathematical psychology. We also connected these models with neurophysiology. To test the hypothesis that movement-related neurons in FEF instantiate an accumulation of evidence, we quantitatively compared measured metrics of neural dynamics with predicted metrics of accumulator dynamics, a method of using neurophysiology to inform model selection. We also systematically examined the relationship between model parameters and predicted model dynamics, finding conditions where variation in different model parameters produced similar variation of predicted model dynamics. These results suggest that neural dynamics can have identifiability limitations just like behavioral data. While neural data can inform model selection, neural data by itself has no empirical primacy and must be considered in conjunction with behavioral data to adjudicate between competing computational models.

Tuesday, 9:40

Bayes

Constraining Cognitive Abstractions Through Bayesian Modeling. Brandon Turner, *Stanford University*,

United States of America, Birte U. Forstmann, *University of Amsterdam*, Eric-Jan Wagenmakers, *University of Amsterdam*, Scott Brown, *University of Newcastle*, Per Sederberg, *The Ohio State University*, Mark Steyvers, *University of California, Irvine*. Scientists who study cognition infer underlying processes either by observing behavior (e.g., response times, percentage correct) or by observing neural activity (e.g., the BOLD response). These two types of observations have traditionally supported two separate lines of study. The first is led by cognitive modelers, who rely on behavior alone to support their computational theories. The second is led by cognitive neuroimagers, who rely on statistical models to link patterns of neural activity to experimental manipulations, often without any attempt to make a direct connection to an explicit computational theory. Here we present a flexible Bayesian framework for combining neural and cognitive models. Joining neuroimaging and computational modeling in a single hierarchical framework allows the neural data to influence the parameters of the cognitive model. Critically, our Bayesian approach can reveal interactions between behavioral and neural parameters, and hence between neural activity and cognitive mechanisms. We demonstrate the utility of our approach with applications to simulated and experimental data.

Joint Modeling of Behavioral and Neural Data (Part II)

Organizer: Brandon Turner

Tuesday, 10:30

Bayes

Rhythmic fluctuations in information accumulation in the human brain. Christopher Summerfield, *University of Oxford, United Kingdom*. Categorical choices are preceded by the accumulation of sensory evidence in favour of one action or another. Current models describe evidence accumulation as a continuous process occurring at a constant rate, but this view is inconsistent with accounts of a psychological refractory period during sequential information processing. During perceptual categorisation, we found that the neural encoding of momentary evidence in the human EEG and its subsequent impact on choice fluctuated rhythmically according to the phase of parietal delta oscillations (2 Hz). By contrast, motor beta-band activity (10–30Hz) encoded the integrated evidence as a response preparation signal. These findings draw a clear distinction between central and motor stages of decision making, with successive samples of evidence competing to pass through a cyclic processing bottleneck before being mapped onto action.

Tuesday, 10:50

Bayes

Evidence accumulation and the emergence of error awareness. Marco Steinhauser, *Catholic University of Eichstätt-Ingolstadt, Germany*, Nick Yeung, *University of Oxford, UK*. Errors in choice tasks have been shown to elicit a cascade of characteristic

components in the human event-related potential (ERP)—the error-related negativity (Ne/ERN) and the error positivity (Pe). In a series of studies, we investigated how these components are related to the emergence of error awareness by testing predictions of models of decision making. Our approach was to consider error awareness as a decision process in which evidence for an error is accumulated until a decision criterion is reached, and to distinguish between two stages of error detection: The accumulated evidence for an error, which is generated by an error monitoring process and which serves as an input signal to error awareness, and the decision output reflecting the awareness that an error has occurred. In Study 1, we investigated which of these stages is reflected by error-related ERP components by manipulating the decision criterion and testing corresponding model predictions. We found that the Pe amplitude correlates with predicted accumulated evidence both on the level of mean ERPs and on a single-trial level. In Study 2, we investigated whether the Pe varies with the predicted output of an error monitor by manipulating the response criterion of the primary task and testing predictions of connectionist models of error monitoring. The results of both studies suggest that the Pe amplitude but not the Ne/ERN reflects the accumulated evidence for an error and that this evidence drives the emergence of error awareness.

Tuesday, 11:10

Bayes

Single Trial Analysis of EEG in Perception and Memory.
Roger Ratcliff, *The Ohio State University, United States of America*, Russ Childers, *The Ohio State University, United States of America*, Troy Smith, *The Ohio State University, United States of America*, Per Sederberg, *The Ohio State University, United States of America.*
The diffusion model for simple decision making can decomposeresponse times and accuracy into components of processingthat reflect the quality of evidence used in a decision, the amount ofevidence required to make a decision, and the duration of stimulus encodingand response production, along with the variability in these componentsacross trials. Research using single and multiunit recordings in primatesand neuroimaging studies in humans have recently begun attempts toidentify where and how the relevant neural computations are carried out.We review a study in perceptual decision making in which a measurederived from single-trial analysis (Sajda & Philiastides) of EEGindexed the quality of the evidence used in the decision process evenwithin a class of nominally identical stimuli. We then present a newstudy of EEG and memory, and perform similar analyses. The analyses showstrong relationships between evidence accumulation in the decisionprocess and a single-trial ERP measure at about 600ms. Measures basedon beta and low gamma frequency analyses and earlier ERP measures show noeffects.

Tuesday, 11:30

Bayes

Practice in a Decision Making Task Induces Ultra-fast Changes in Structural White Matter Tracts: A model-based approach.
Birte U. Forstmann, *University of Amsterdam, The Netherlands*, Wouter Boekel, *University of Amsterdam, The Netherlands*, Dora Matzke, *University of*

Amsterdam, The Netherlands, Eric-Jan Wagenmakers, *University of Amsterdam, The Netherlands*, Scott Brown, *University of Newcastle, Australia*. Everyday life requires rapid adjustments to a changing environment. How does the brain and, more specifically, how do white matter fibers implement rapid strategic adjustments in behavior? In this study, we tested healthy young participants to examine whether ultra-fast increases in cortico-subthalamic white matter connections are associated with behavioral strategic adjustments expressed as changes in response caution during stopping a motor response in a stop-signal paradigm. Connection strength was quantified using probabilistic diffusion weighted imaging. A new mathematical model was developed to quantify response caution in stopping a motor response. The results suggest that increased changes in cortico-subthalamic connection strength predict interindividual changes in response caution after only 45 min of behavior. This increase in white matter tract strength continues to predict behavior over the course of hours and weeks. The present findings give insight in ultra-fast white matter tract strength changes in simple decision-making tasks.

Tuesday, 11:50

Bayes

Selective integration of sensory evidence by recurrent dynamics in prefrontal cortex. Valerio Mante, *ETH/University Zürich, Switzerland*. Prefrontal cortex is thought to play a fundamental role in flexible, context-dependent behavior, but the exact nature of the computations underlying this role remains largely mysterious. In particular, individual prefrontal neurons often generate remarkably complex responses that defy deep understanding of their contribution to behavior. Here we study prefrontal cortex in monkeys trained to flexibly select and integrate noisy sensory inputs towards a choice. We find that the observed complexity and functional roles of single neurons are readily understood in the framework of a dynamical process unfolding at the level of the population. The population dynamics can be reproduced by a trained recurrent neural network, which reveals a previously unknown mechanism for selection and integration of task-relevant inputs. This mechanism implies that selection and integration are two aspects of a single dynamical process unfolding within the same prefrontal circuits, and potentially provides a novel, general framework for understanding context-dependent computations.

Tuesday, 12:10

Bayes

The effects of neural gain on attention and learning. Eran Eldar, *Princeton University, United States of America*, Jonathan D. Cohen, *Princeton University, United States of America*, Yael Niv, *Princeton University, United States of America*. We used simple neural networks to generate a set of behavioral and neural predictions concerning the effect of global variations in gain on attention in learning and perception tasks. Behaviorally, we predicted high gain to be associated with narrower attention, and thus with learning that is focused on stimulus features to which participants were predisposed to attend. In addition, the models predicted that the effect of high gain would be reflected by clustering of neural functional connectivity. These predictions were supported by the results of a set of behavioral and fMRI experiments,

in which we used pupil diameter as an indirect index of gain. Furthermore, supporting our interpretation of these results in terms of variations in gain, we showed that changes in pupil diameter were associated with changes in the fMRI data that are predicted by changes in global levels of gain, including more extreme BOLD activations and global fluctuations in functional connectivity.

Abstracts For Talks

(Abstracts organized by day, session, and presentation order)

Cognitive Modeling

Chair: Joachim Vandekerckhove

Monday, 10:30

Euler

The Similarity-Updating Model of Probability Judgment and Belief Revision. Mirjam A. Jenny, *Max Planck Institute for Human Development, Germany*, Jörg Rieskamp, *University of Basel*, Håkan Nilsson, *Uppsala University*. When people revise their beliefs on the basis of new information, they often take irrelevant information into account. Although this "dilution effect" has been found in diverse areas, few studies have modeled the underlying cognitive processes. To explain the cognitive processes we suggest a similarity-updating model, which incorporates a similarity judgment inspired by similarity models of categorization research and a weighting and adding process suggested in judgment studies. We illustrate the predictive accuracy of the model for probability judgments and belief revision with three experimental studies. In the experiments participants received samples from two categories and had to judge which category the samples stemmed from. The similarity-updating model predicts that this probability judgment is a function of the similarity of the sample to the categories. When presented with a new sample, the previous probability judgment is updated with a second probability judgment by taking a weighted average of the two. The model describes people's probability judgments well and outcompetes a Bayesian model and alternative accounts of belief revision. The model also correctly predicts the dilution effect according to which non-diagnostic information "dilutes" the probability judgment. Additional simulations show that the similarity-updating model predicts a substantial amount of dilution effects. However, the simulation also shows that the model often produces adaptive judgments, especially when the amount of noise in the environment is reduced. In sum, the similarity-updating model provides an adaptive account of human probability judgment and belief revision.

Monday, 10:50

Euler

How PDP Models Learn Quasiregularity. Woojae Kim, *The Ohio State University, United States of America*, Mark A. Pitt, *The Ohio State University, United States of America*, Jay I. Myung, *The Ohio State University, United States of America*. Parallel Distributed Processing (PDP) models have had a profound impact on the study of cognition. One domain in which they have been particularly influential is quasiregular learning, in which mastery requires both learning regularities that

capture the majority of the variability in the input plus learning exceptions that violate the regularities. How PDP models learn quasiregularity is still not well understood. Large-scale analyses of a feedforward, three-layer network were carried out to answer fundamental questions about network functioning, such as how the model can learn both regularities and exceptions without sacrificing performance, and the nature of the hidden representation that makes this possible. Analysis of a small-scale network explained at a microscopic level how the network acquires these abilities. Together the results expand our understanding of learning in a single-route network. Theoretical and methodological implications of the findings are also discussed.

Monday, 11:10

Euler

On optimality conditions for the likelihood difference heuristic. Jonathan D. Nelson, *Max Planck Institute for Human Development, Germany*, Christine Szalay, *Max Planck Institute for Human Development, Germany*, Björn Meder, *Max Planck Institute for Human Development, Germany*, Vincenzo Crupi, *Ludwig Maximillian University, Munich, Germany*, Gerd Gigerenzer, *Max Planck Institute for Human Development, Germany*, Katya Tentori, *University of Trento, Italy*. Consider the task of selecting a medical test to determine whether a patient has a disease. Normatively, this requires considering the base rate of the disease, the true and false positive rate for each test, and the payoffs and costs for correct and incorrect diagnoses. Due to multiple sources of uncertainty, however, these quantities are seldom precisely known. Are there shortcuts or heuristic strategies that could approximate calculation of tests' objective value, if the precise payoffs are unknown? Can pure information strategies (which disregard the objective utilities) sometimes identify the objectively most useful test? We study the performance of the likelihood difference heuristic for test selection. This extremely simple heuristic selects the test with the highest likelihood difference, or difference between true and false positive rate, ignoring all other information. We prove that despite its simplicity, the likelihood difference heuristic identifies the objectively most useful test under certain conditions. This holds if the base rate of the disease equals the threshold probability above which it is best to act as if the patient has the disease. In other circumstances, the likelihood difference heuristic is not in general optimal but can perform remarkably well. In further simulation studies we explore the circumstances under which other pure information strategies, such as information gain and probability gain, also tend to identify the objectively more useful test.

Monday, 11:30

Euler

Building cognitively plausible models of decision strategies in ACT-R. Cvetomir M. Dimov, *University of Lausanne, Lausanne, Switzerland*, Julian N. Marewski, *University of Lausanne, Lausanne, Switzerland*, Lael J. Schooler, *Max Plank Institute of Human Development, Berlin, Germany*. Do people follow a non-compensatory or a compensatory decision process? In what situations do these decision processes better describe people's behavior? These two ques-

tions have emerged as central in inference research. Tackling them calls for a strategy classification method which clearly distinguishes between various compensatory and non-compensatory decision strategies. Methods based solely on outcome data are insufficient, because different strategies make highly overlapping outcome predictions. Additional dependent variables are therefore needed, such as the decision times associated with using a strategy. Yet, even well-researched strategies are often not defined with sufficient precision to enable quantitative decision time predictions. We provide a primer on how underspecified decision strategies can be transformed into highly specific cognitive models within a cognitive architecture such as ACT-R. Cognitive architectures are quantitative theories that integrate models of various cognitive functions, such as memory, perception and action, into a unified framework. Implementing a strategy into a cognitive architecture increases its degree of specification, but also leaves many degrees of freedom to constrain, which is manifested in the myriad of implementations possible for each strategy. In order to identify the correct implementation, we developed the instruct-paradigm, in which participants are instructed to rely precisely on one strategy. The memory, response and decision time data collected is then used to filter out the unrealistic ACT-R implementations. We built ACT-R models of three classic strategies: the compensatory weighing weighted-linear model, the compensatory equal-weight tallying heuristic and the non-compensatory take-the-best heuristic. We then ran an experiment with the instruct-paradigm with three between-subject conditions corresponding to above-mentioned decision strategies. The experimental data allowed us to identify the correct ACT-R models of the decision strategies. It additionally provided us with insights into how the learning phase influences the decision process. Finally, the participants' response times in the tallying and weighted-linear model conditions deviated from previous experiments, in which participants were classified as users of these strategies.

Monday, 11:50

Euler

A cultural consensus theory model for the polytomous data case. Royce Anders, *University of California, Irvine, United States of America*, William Batchelder, *University of California, Irvine, United States of America*. This presentation introduces the first Cultural Consensus Theory (CCT) model for polytomous data, the Latent Truth Rater Model (LTRM). The LTRM is a hierarchical latent-trait, signal-detection-based rater model, in which relationships between latent item appraisals and category thresholds give rise to observed responses. The LTRM includes novel aspects than preceding consensus rater models, and provides a cognitive modeling of rater bias; how individuals may differential perceive and utilize the rating scale. The model also estimates item location values in [0,1], item difficulty, and individual knowledge via hierarchical Bayesian inference. An augmented, finite-mixture case of the model is also developed for cases in which subgroups may share different consensuses from one another. These models are demonstrated on two real data sets, one involving judgments of grammaticality and another involving knowledge about particular cities; results are also demonstrated on simulated data sets. Posterior predictive checks based on

properties of the model are also included.

Monday, 12:10
Euler

Cognitive latent variable models. Joachim Vandekerckhove, *University of California, Irvine, United States of America*. We introduce cognitive latent variable models, a broad category of formal models that can be used to aggregate information regarding cognitive parameters across participants and tasks. Latent structures are borrowed from a vast literature in the field of psychometrics, and robust cognitive process models can be drawn from the cognitive science literature. The new modeling approach allows model fitting with smaller numbers of trials per task if there are multiple participants, and is ideally suited for uncovering correlations between latent task abilities as they are expressed in experimental paradigms. Example applications deal with the structure of cognitive abilities underlying a perceptual task, and executive functioning.

Decision Making 1

Chair: Richard A. Chechile

Monday, 10:30
Fechner

Advances in Prescriptive Decision Theory. Konstantinos Katsikopoulos, *MPI for Human Development, Germany*. Prescriptive decision theory specifies the relative performance of different models under various conditions. Besides being interesting in its own right, prescriptive theory also has implications about describing which models people actually use under which conditions. For a long time, prescriptive decision theory was developed in disciplines such as operations research, management science and economics. The goal was to identify a decision alternative that optimized a multi-attribute utility function which was assumed to have known parameters. In recent decades, psychology has made a three-fold contribution to prescriptive decision theory. First, it suggested that people do not always seek to optimize. This led to some empirical evaluations of the relative performance of optimizing models and heuristics studied by psychologists. Second, psychologists realized that the best-fitting parameters of models (both optimizing and heuristic) should not be always assumed to be known. This led to the systematic evaluation, by computer simulations, of the relative performance of heuristics and optimizing models in problems of prediction. Third, mathematical analyses uncovered general conditions for the optimal, perfect or near-perfect performance of models such as linear optimizers and lexicographic heuristics. In this talk, I review these contributions, discuss open problems and argue for the need for further synthesis.

Monday, 10:50
Fechner

Social competition affects information search and choice. Nathaniel D. Phillips, *Max Planck Institute for Human Development, Germany*, Ralph Hertwig, *Max Planck Institute for Human Development, Germany*, Yaakov Kareev, *The Hebrew University of Jerusalem*, Judith Avrahami, *The Hebrew University of Jerusalem*. Decision-making tasks frequently involve choosing between uncertain options whose probability distributions are unknown a

priori. In these tasks, organisms must balance the informational benefits of exploring novel options to estimate their quality with the immediate benefits of exploiting options that are believed to have high quality. This exploration-exploitation trade-off has been studied in a variety of domains where decision-makers act alone (e.g, multi-armed bandits, secretary problems). In the current research, we explore how organisms manage this trade-off in socially competitive situations, such as obtaining a mate or finding a home. We designed an experimental paradigm where participants search for information about two choice options side-by-side with a competitor wherein one player's choice consumes the chosen option and thus removes it from the other player's choice set. In an empirical study using the paradigm, we found that social competition dramatically reduced pre-decisional information search relative to a solitary condition and that participants who stopped search early obtained higher payoffs on average than those who waited. Next, we mathematically derived optimal stopping rules from this paradigm and found that optimal search lengths vary systematically as a function of the choice environment (i.e., the gambles), and the social context (i.e., the stopping rules of one's competitors). For example, options with skewed payoff distributions, especially those with extreme rare events, tend to favor longer search, while being in the presence of competitors who choose quickly tends to favor shorter search. The effects of competition we measured empirically appeared to be consistent with the principles of optimal search that we derived.

Monday, 11:10

Fechner

Implementing Heuristic Rules in Preference Accumulation Networks. Sudeep Bhatia, *Carnegie Mellon University, United States of America.* This paper presents a connectionist accumulation network that can perform the types of symbolic computations specified by multi-attribute heuristic choice rules. This network is similar to previous preference accumulation models in most ways, except for attribute processing and activation functions. Self-feedback and lateral inhibition, biological properties typically applied only to accumulator nodes, are also assumed to be active in network layers representing decision attributes. Additionally, all nodes are assumed to have a piecewise linear activation function, bounded at zero and one. With these assumptions, the network is able to accurately implement the lexicographic choice rule, the CONF heuristic, elimination by aspects, elimination by least attractive, the majority of confirming dimensions heuristic, weighted pros, DOMRAN, equal weights, the additive difference rule, and rational choice. More specifically, for any set of choice objects and any of the above heuristic rules, some combination of connection weights and acceptance/rejection thresholds that generates the choice specified by the heuristic rule, is guaranteed to exist. The results of this paper demonstrate how sequential sampling and accumulation—a framework generally used to describe only low-level decisions—can be modified to study complex, high-level cognition, such as rule based decision making. These results also indicate that heuristic choice and preference accumulation, two highly

influential approaches to studying preferential choice, are fully compatible, with the descriptive power and theoretical insights of one approach transferring easily to the other.

Monday, 11:30

Fechner

Why and How to Measure the Association between Choice Options. Sandra M. Andraszewicz, *University of Basel, Switzerland*, Jörg Rieskamp, *University of Basel, Switzerland*. Prominent theories of decision making, such as proportional difference model, priority heuristics, decision field theory and regret theory assume that people do not evaluate options independently of each other. Instead, these theories predict that people compare the options' outcomes with each other. Therefore the theories' predictions strongly depend on the association between outcomes. In the present work, we examine how the association between options can be best described. Interestingly, a great part of research of decision making employs options with only two outcomes. For these options, the standard correlation measure between option's outcomes does not provide a meaningful interpretation, as it equals to either 1 or -1. Therefore, we propose the standardized covariance between options A and B, denoted as a sigma-star. With the use of numerous simulations, we describe the properties and interpretation of this measurement and show its similarities and differences with the correlation measurement. Also, we extend the application of the standardized covariance to options with four options. Finally, we show how the predictions of different models of decision making vary depending on the value of the standardized covariance. In sum, we highlight the importance of controlling for the association between options' outcomes and propose an easy-to-use method of its' measurement.

Monday, 11:50

Fechner

Cheap but Clever: Human Active Learning in a Bandit Setting. Shunan Zhang, *University of California, San Diego, United States of America*, Angela J. Yu, *University of California, San Diego, United States of America*. How people achieve long-term goals in an imperfectly known environment, via repeated tries and noisy outcomes, is an important problem in cognitive science. There are two interrelated questions: how humans represent information, both what has been learned and what can still be learned, and how they choose actions, in particular how they negotiate the tension between exploration and exploitation.In this work, we examine human behavioral data in a multi-armed bandit setting, in which the subject chooses one of four "arms" to pull on each trial and receives a binary outcome (win/lose). We consider a range of models, varying in the complexity of both information representation and action policy. Here, we analyze a new model for human bandit choice behavior, based on the knowledge gradient (KG) algorithm, which has been developed by Frazier, Powell, and Dayanik (2008) to solve problems in operations research. At each time step, the KG policy chooses, conditioned on previous observations, the option that maximizes future cumulative reward gain. It is based on the myopic assumption that the next observation is the last one used to learn about the environment, and will rely on that knowledge for all remaining trials. Unlike previously pro-

posed algorithms, which typically assumes the exploration mode is completely random, KG provides a more sophisticated and discriminating way to explore. On the other hand, KG is computationally much simpler than the optimal algorithm.Our analysis supports the KG decision policy under the Bayesian meta learning of the environment as a good fit to human data in bandit problems. Our result implies that people might learn the individual reward rates as well as the general environment, and the shared, latent environment induces a special type of correlation among the bandit arms. For the control component, our result supports the KG policy that directly optimizes the semi-myopic goal-maximizing future cumulative reward while assuming only one more time step of exploration and strict exploitation thereafter.

Monday, 12:10

Fechner

Assessing Risky Weighting Functions via their Logarithmic Derivative Function. Richard A. Chechile, *Tufts University, United States of America*, Daniel H. Barch, *Tufts University, United States of America*. In cumulative prospect theory, the outcome probabilities for a gamble are transformed and serve as weighting functions for the different outcome utilities. For example, for a binary lottery with outcomes V_1 with probability p and V_2 with probability $1-p$, the utility representation for the gamble is $U(G) = \xi(p)u(V_1) + [1 - \xi(p)]u(V_2)$, where $\xi(p)$ is the risky weighting function, and where $u(V_1)$ and $u(V_2)$ are the outcome utilities. A number of proposals for the risky weighting function have been advanced in the psychological and economics literature, but it has been difficult to reach a consensus on a specific function. In this paper, we show that powerful discriminatory evidence is obtained by comparing the theoretical and empirical values of the logarithmic derivative function for $\xi(p)$. The logarithmic derivative function (LD) is similar to a reverse hazard function and is very sensitive to the curvature of a function. Given the data for particular matched gambles, estimates of the LD function can be obtained without assuming the form of either the risky weighting function or the outcome utility function. These LD estimates provide evidence against most of the existing proposals for the risky weighting function, but are consistent with two functions.

Bayesian Modeling

Chair: Stephan Lewandowsky

Monday, 1:50

Euler

The Biasing Influence of Worldview on Climate Change Attitudes and Belief Polarization. John Cook, *University of Queensland, Australia*, Stephan Lewandowsky, *University of Western Australia, Australia*. It is well established that political ideology has a strong influence on public opinion about climate change. There is also evidence of ideologically driven belief polarization, where two people receiving the same evidence update their beliefs in opposite direction. Presenting scientific evidence for climate change can result in a "backfire effect" where conservatives become more sceptical. It is possible to simulate the backfire effect using Bayesian Networks, which simulate rational belief updating using Bayes Law. In this model, trust in scientists is the driving force behind polarization and worldview is the knob that influences trust. One consequence of this

model is that interventions that seek to increase trust in science are expected to be ineffective for conservatives. A potentially constructive approach to reduce the biasing influence of worldview is by affirming conservative values. Experimental data comparing the effectiveness of various interventions are presented and discussed in the context of the Bayesian Network model.

Monday, 2:10
Euler

Bayes Theorem, Mutual Information, and Shannon Source/Channel Coding: An Information Geometric Perspective. JUN ZHANG, *University of Michigan, United States of America*. We revisit Bayes formulation from the perspective of Shannon's Coding Theory, where prior probability p (on sample space X) is viewed as a probability on the input alphabets, marginal probability q (on evidence space Y) as a probability on the output alphabets, and likelihood function $Q(y|x)$ as the transition probability of a memory-less but lossy channel transmitting messages from an input to the output (i.e., a representation of the input). Coding theory deals with two aspects of information transmission that are dual to each other: coding of the source (addressing data compression aspect) and coding of the channel (addressing error-correction aspect). Rate distortion and channel capacity functions are classical measures established through an inequality based on mutual information. A refined analysis shows that actually two separate inequalities are involved, one concerning "marginalization loss" when the marginal probability q is inconsistent with prior probability p and the likelihood function Q, and another concerning "normalization gain" when the posterior probability $P(x|y)$ is consistent with (calculated by) the Bayes formula. We then investigate the use of Tsallis entropy (the extension of Shannon entropy to non-extensive systems) and q-exponential family (the extension of Boltzmann-Gibbs distributions to heavy-tail statistics) in source and channel coding. Corresponding rate-distortion and channel capacity measures can be derived, along with the (generalized) q-version of "Blahut-Arimoto algorithm" (an iterative procedure for computing the above measures). This approach provides a full, information geometric articulation of reference-representational duality in information theory, where minimaximizing mutual information (i.e., Kullback-Leibler divergence between the product of p and q and a joint distribution on X and Y) characterizes learning and adaptation.

Monday, 2:30
Euler

Bayesian Inference and Model Comparison for Random Choice Structures. WILLIAM J. MCCAUSLAND, *University of Montreal, Canada*, A.A.J. MARLEY, *Victoria University, Canada*. We consider an environment in which agents face various choice sets, as- sembled from a finite universe of objects, and choose a single object each time a choice set is presented to them. Models for probabilistic discrete choice give, for each choice set, a discrete probability distribution over that choice set. We use methods of Bayesian model comparison to measure the empirical plausibility of various axioms of probabilistic discrete choice. Our testing ground is a model with very little structure. A priori, there are no restrictions on choice distributions across choice sets. We reanalyze several existing data sets, including ones obtained using ex-

perimental designs intended to elicit intransitive revealed preferences. We find empirical evidence in favour of random utility, the hypothesis that all choice probabilities are governed by a random utility function over the universe of objects. We also find evidence against the multiplicative inequality of Sattath and Tversky (1976). Since the multiplicative inequality is a necessary condition for independent random utility, a refinement of random utility stipulating that the utilities of objects are mutually independent, this constitutes evidence against independent random utility.

Monday, 2:50
Euler

Rats in a T-maze: a Bayesian clustering model. David Leslie, *University of Bristol, United Kingdom*, Kevin Lloyd, *University of Bristol, United Kingdom*. The phenomenon of serial reversal-learning is difficult to explain without some form of context-learning. Differentiating between such contexts allows an animal to rapidly adapt its behaviour when context changes occur. The current work views animals as making sequential inference in an environment assumed to follow a Chinese restaurant process with inertia and full Bayesian inference is approximated by a sequential-sampling scheme in which only a single hypothesis about current context is maintained. Actions are selected via Thompson sampling, allowing uncertainty in parameters to drive exploration in a straightforward manner. In simple two-alternative choice problems with switching reinforcement schedules the model exhibits behaviour comparable with rat data from a number of T-maze studies: spontaneous recovery, the effect of partial reinforcement on extinction and reversal, the overtraining reversal effect, and serial reversal-learning effects.

Monday, 3:10
Euler

Differences between Observed and Latent Confidence in Rank Ordering. Brent Miller, *University of California, Irvine*, Mark Steyvers, *University of California, Irvine*. We have shown previously that for more complex tasks such as rank ordering, when subjects are offered an ordering from a previous subject, they will predominantly move items that improve the ordering, on average. We have theorized that subjects have a latent uncertainty about their knowledge which guides their decision behavior when they are collaborating in a limited, iterative learning fashion. Is it possible to measure the uncertainty that generates this behavior? In this study, we examine subjects reconstructing the order of time-based and magnitude-based series of items from memory, and have them supply confidence ratings for their item placement. After a distractor task, subjects perform the same task again, receiving the final ordering of a previous participant. This sequential collaborative behavior increases accuracy as subjects tend to only move items for which they have a high certainty. We introduce a Bayesian version of a Thurstonian model to show how each subject updates the previous individual's ordering based on their uncertainty. We then compare the model's measure of latent uncertainty with their explicit confidence ratings, and compare how each indicates the actual uncertainty of a subject's knowledge.

Monday, 3:30

Euler

An Integrative Bayesian Approach to Cognitive Modeling. Sean Tauber, *University of California, Irvine, United States of America*, Mark Steyvers, *University of California, Irvine, United States of America*. I will discuss methods for integrating rational models and Bayesian data analysis. The motivation for this research is that it would be useful to have a sensible and generally applicable framework for the quantitative comparison and evaluation of rational models. This integrative approach allows us to relax some of the assumptions of rational models. For example, instead of assuming that people's mental representations are veridical with environmental statistics, we can apply Bayesian data analysis to a rational model in order to estimate people's subjective prior knowledge—including individual differences. Another benefit of this approach is that we can apply hierarchical Bayesian methods to directly compare competing rational models, not only with each other, but with process models that are at Marr's algorithmic level. This allows researchers to "bridge levels of analysis" using an integrative Bayesian approach.

Reaction Times

Chair: Ehtibar N. Dzhafarov

Monday, 1:50

Fechner

Simple correction methods for task completion times contaminated by errors, outliers and omissions. Matthias Gondan, *University of Copenhagen, Denmark*, Bruno Fimm, *University Hospital Aachen, Germany*. In experimental psychology, psychometrics, and applied evaluative research, inference on behavioral performance is often based on task completion times, for example, the time it takes to respond to a visual signal, or to choose among a number of alternatives in a multiple choice task. When the intensity of the signal is low or the task is difficult, or both, patients usually do not respond with 100% accuracy. In such a situation, estimation of response speed is difficult because the task completion times are contaminated by outliers, omitted and erroneous responses. Analysis of response speed is often based on the subset of correct responses only, which is known to yield biased estimates and does not make full use of the available information. We present simple ad hoc data cleaning methods for task completion times contaminated by outliers, omissions and erroneous responses, and we show that these methods can substantially reduce bias and uncertainty of estimates of response speed. The method is illustrated using data from an evaluation of integrated displays in intensive care units.

Monday, 2:10

Fechner

The $2N$-ary choice tree model for N-alternative preferential choice — implementation and parameter estimation. Lena Maria Wollschläger, *Jacobs University Bremen, Germany*, Adele Diederich, *Jacobs University Bremen, Germany*. The $2N$-ary choice tree ($2NCT$) model is an approach designed for decision problems with multiple alternatives that are described on multiple attributes. It focusses on the motivational and cognitive mechanisms during the deliberation process and takes into account the dynamic nature of decision making behavior. The model predicts

choice response times and choice probabilities by defining a random walk on a tree, the $2N$-ary choice tree. The dynamic of the random walk is based on attribute-wise iterated comparison of the alternatives to several reference points, decay of the previously sampled information over time and noise. Expected choice probabilities and response time distributions are given in closed form for optional and fixed stopping times. Here we show how the model can be implemented, how choice probabilities and response times can be determined and how they can be used to re-discover the model parameters from simulated data.

Monday, 2:30
Fechner

BEESTS: Software package for the Bayesian estimation of stop-signal reaction time distributions. Dora Matzke, *University of Amsterdam, Netherlands, The*, Scott Brown, *University of Newcastle*, Gordon D. Logan, *Vanderbilt University*, Jonathon Love, *University of Amsterdam, Netherlands, The*, Thomas Wiecki, *Brown University*, Eric-Jan Wagenmakers, *University of Amsterdam, The Netherlands*. The cognitive concept of response inhibition is often measured using the stop-signal paradigm. In this paradigm, participants perform a two-choice response time task where the primary task is occasionally interrupted by a stop-signal that instructs participants to withhold their response. The dependent variable of interest is the latency of the unobservable stop response (stop-signal reaction time or SSRT). Recently, Matzke, Dolan, Logan, Brown and Wagenmakers (2013) developed a Bayesian parametric approach that allows for the estimation of the entire distribution of SSRTs. The Bayesian parametric approach assumes that SSRTs are ex-Gaussian distributed and relies on Markov chain Monte Carlo sampling to obtain posterior distributions for the parameters of the SSRT distribution. Here we present a software implementation of the Bayesian parametric approach that can be applied to individual as well as hierarchical data structures. The application comes with an easy-to-use graphical user interface and provides users with summary statistics of the posterior distributions of the parameters as well various diagnostics tools to assess the quality of the parameter estimates. The software is freely-available and runs on OS X and Windows operating systems.

Monday, 2:50
Fechner

Competitive Guided Search: Meeting the challenge of benchmark RT distributions. Rani Moran, *Tel Aviv University, Israel*, Michael H. Zehetleitner, *Ludwig-Maximilians-Universität München*, Hermann Müller, *Ludwig-Maximilians-Universität München; Birkbeck College, University of London*, Marius Usher, *Tel Aviv University, Israel*. Visual search models were mainly evaluated based on their account of mean RTs and accuracy data. Recently, Wolfe, Palmer and Horowitz (2010) have demonstrated that the shape of the entire RT distributions imposes important constraints on visual search theories and can falsify even successful models such as Guided Search, raising a challenge to computational theories of search. Competitive Guided Search is a novel model that meets this important challenge. The model is an adaptation of Guided Search, featuring a series of item selection and identification iterations with guidance towards targets. The

main novelty of the model is its termination rule: A quit unit, which aborts the search upon selection, competes with items for selection and is inhibited by the saliency map of the visual display. As the trial proceeds, the quit unit both increases in strength and suffers less saliency-based inhibition and hence the conditional probability of quitting the trial accelerates. The model is fitted to data from three classical search task that have been traditionally considered to be governed by qualitatively different mechanisms, including a spatial configuration, a conjunction and a feature search (Wolfe et al., 2010). The model is mathematically tractable and it accounts for the properties of RT distributions and for error rates in all three search tasks, providing a unifying theoretical framework for visual search.

Monday, 3:10
Fechner

A snake wiggle of reaction time functions to indicate holistic perception. Mario Fific, *Grand Valley State University, United States of America*, Daniel R. Little, *The University of Melbourne, Australia*. We analyzed the underlying fundamental processes engaged in forming holistic perceptualrepresentations. The subjects participated in a face categorization task over multiple sessions. We applied the systems factorial technology (SFT) to analyze the properties of the observed response time (RT) distributions. The key statistic was a survivor interaction contrast function (SIC). Over the course of extensive practice, the observed SICs exhibited a specific pattern of shape transformations that could be described as a "snake wiggle". The observed SIC signature indicated that the processing mechanism behind holistic perception relies on strong positive facilitation between feature detectors, within the parallel mental network. The converging evidence is provided by the additional qualitative RT test(Fific, Little & Nosofsky, 2010).

Monday, 3:30
Fechner

Revealing mental processing architectures with selectively influenced components. Ehtibar N. Dzhafarov, *Purdue University, United States of America*. The following is classical problem in psychology. We assume that a task is performed by a series-parallel network of processes with all-AND gates or all-OR gates. We assume that this network contains two processes that are selectively influenced by two experimental factors. We allow for the processes in the network to be stochastically interdependent. We observe overall performance times and construct distribution functions for them at each possible treatment. The question is: Can we identify (a) whether the gates in the network are OR or AND; and (b) whether the two selectively influenced processes are sequential or parallel? A solution for this problems is known within the framework of the theory of selective influences developed by Dzhafarov and colleagues. It uses the interaction contrast of distribution functions and several ancillary assumptions: simple stochastic dominance, existence of densities and means, and, for some results, certain ordering of density functions. The present work uses one of several equivalent definitions of selective influences to arrive at the solution with no ancillary assumptions except for a version of simple stochastic dominance. This solution reduces the problem involving random variables to a combinatorial problem with deterministic quantities only.

Hypothesis Testing

Chair: Eric-Jan Wagenmakers

Monday, 4:20
Euler

A statistical test of the dimensionality of the state-trace plot.. John Cameron Dunn, *University of Adelaide, Australia*, Michael Kalish, *University of Louisiana at Lafayette, USA*, Oleg Burdakov, *University of Linköping, Sweden*. State-trace analysis is a general method to determine whether the effects of two or more independent variables on two or more dependent variables are mediated by one or more than one latent variable. The state-trace plot is a parametric plot of the observed values of a set of dependent variables obtained under conditions defined by the conjunction of a set of independent variables. In general, the number of latent variables places an upper limit on the dimensionality of the state-trace plot. We consider the problem of testing the hypothesis that the state-trace plot is one-dimensional under the assumption that each dependent variable is an unknown but monotonically increasing (or decreasing) function of a single latent variable. In this case, the state-trace plot conforms to a monotonically increasing (or decreasing) curve. We outline a new statistical test of this hypothesis based on the coupled monotonic regression algorithm (Burdakov, Dunn & Kalish, 2012) and demonstrate its application to several relevant data sets. Reference: Burdakov, O.P., Dunn, J.C., & Kalish, M.L. (August, 2012). An approach to solving decomposable optimization problems with coupling constraints. *21st International Symposium on Mathematical Programming, Berlin.*

Monday, 4:40
Euler

Considering the Null. Maarten Speekenbrink, *University College London, United Kingdom*. While still the dominant method of statistical inference in psychology, null hypothesis significance testing (NHST) is controversial. Recently, there have been calls to replace traditional (frequentist) NHST with a Bayesian alternative using Bayes factors (e.g., Rouder et al., 2009; Wagenmakers, 2007). These Bayesian hypothesis tests weight the evidence for two statistical models, a null model in which the value of a parameter of interest is assumed to be known exactly, and an alternative model in which the value of the parameter is unknown as reflected by a diffuse prior distribution. While Bayesian tests resolve many of the problems that plague the traditional NHST, they are associated with the same "methodological paradox" noted by Meehl (1967) for the NHST, in that experimental improvement (such as an increase sample size) typically results in weaker corroboration of a theory, as the test of the theory becomes more lenient. In rejecting the null hypothesis, one effectively rejects full knowledge in favour of (near) complete ignorance. Stated this way, it seems surprising that rejection of the null hypothesis is met with such a favourable response. The traditional focus on determining whether a parameter is likely to have a particular (null) value may be better served by Bayesian estimation and credibility intervals (cf. Kruschke, 2013). Hypothesis testing may be more valuable after a reformulation of the null hypothesis. The present work explores a Bayesian hypothesis testing procedure in which the

null hypothesis reflects a state of complete ignorance or lack of knowledge. The procedure has some useful properties, amongst which the imperative to develop informative hypotheses and an associated drive towards cumulative theory development. References: Kruschke, J.K. (2012, July 9). Bayesian Estimation Supersedes the t-Test. *Journal of Experimental Psychology: General.* Advance online publication. (doi: 10.1037/a0029146); Rouder, J.N., Speckman, P.L., Sun, D., Morey, R.D., & Iverson, G. (2009). Bayesian t-tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review, 16,* 225–237; Wagenmakers, E.-J. (2007). A practical solution to the pervasive problems of p values. *Psychonomic Bulletin & Review, 14,* 779–804.

Monday, 5:00

Euler

Default Bayes factors for crossed random effects designs. Josine Verhagen, *Universiteit van Amsterdam, The Netherlands*, Eric-Jan Wagenmakers, *Universiteit van Amsterdam, The Netherlands*, Richard D. Morey, *Rijksuniversiteit Groningen, The Netherlands*. We present a default Bayes factor hypothesis test for crossed random effects designs. In these designs, popular in linguistics and related fields, both subjects and stimuli are modeled as random effects. Random effects models are a natural extension of the standard ANOVA approach, an approach for which Bayesian contributions have been surprisingly modest. Here we demonstrate how to test hypotheses conditional on crossed random effects using default Bayes factors based on the "Jeffreys-Zellner-Siow" framework. Bayes factors have many advantages over p-values. One major advantage is the ability to evaluate evidence in favor of the null hypothesis. The advantages of Bayes factors in crossed random effects designs are highlighted by the re-analysis of two well-known data sets.

Monday, 5:20

Euler

Modeling the effect of hypothesis sparsity on confirmation bias. Andrew Hendrickson, *University of Adelaide, Australia*, Daniel Navarro, *University of Adelaide, Australia*, Amy Perfors, *University of Adelaide, Australia*. The confirmation bias in the domain of hypothesis testing has most often been considered to be a departure from a rational method of sampling information when choosing between hypotheses. Recent theoretical work has argued that this preference for testing items that will confirm hypotheses rather than falsify them (the Positive Test Strategy) can be optimal in environments where more items falsify than confirm each hypothesis. Not only do the rational analyses rely on the sparsity of hypotheses to explain PTS, they actually imply the opposite result when hypotheses are non-sparse. When hypotheses are non-sparse, the value of negative evidence increases. This allows a natural empirical test: if PTS is an irrational bias, it should not depend on the kinds of hypotheses people entertain. If, however, PTS is more correctly viewed as a rational learning strategy in particular environments, its prevalence should increase as hypotheses are increasingly sparse. In this current work we test these theoretical predictions using data from a variant of the classic Battleship game where participants attempt to learn about the configuration of items in a grid

by querying information about specific grid locations, we will present a Bayesian model of how learners adjust their beliefs about ship configuration hypotheses as they actively generate positive and negative test items across hypothesis spaces that vary in size and sparseness distribution. The implications for a rational model that includes confirmation bias will be discussed.

Decision Making 2

Chair: Lawrence T. DeCarlo

Monday, 4:20
Fechner

Selective attention modulates the effect of contingencies on the perceptual decision process. Cheng-Ta Yang, *National Cheng Kung University, Taiwan, Republic of China*, Ting-Yun Chang, *National Cheng Kung University, Taiwan, Republic of China*. Contingencies can be implicitly learned to affect human behavior. Our previous study (Yang, Chang, & Wu, 2013) showed that implicit learning for probability information affected the decision strategy when redundant features of an object are processed for change decision. However, it is unknown whether processing redundant information from different spatial locations is affected by implicit learning for contingencies as visual primitives across space are assumed to be parallelly processed. This study investigated the perceptual decision process in a double-dot paradigm by manipulating the target probability and instructions. We followed the suggestions of systems factorial technology to conduct experiments and analyze data. In Experiment 1, dots were equally probable to be presented at two different locations. In Experiments 2 and 3, dots were more likely to be presented at a location than another. In Experiment 3, the participants were instructed to pay more attention to the location with higher target probability. Results from Experiments 1 and 2 showed that all the three participants adopted parallel self-terminating processing regardless of the relative target probability. In Experiment 3, two participants altered their decision strategies to serial self-terminating processing but one still adopted parallel self-terminating processing. In all the experiments, the process capacity was generally limited. Taken together, individual differences were observed: relative target probability only affected two participants' decision strategies especially when spatial attention was manipulated. Selective attention is necessary for implicit learning for contingencies which may affect the adoption of decision strategies. In order to optimize performance, redundant information across space can be serially processed for decision making.

Monday, 4:40
Fechner

Heuristic Decision Making in One-Shot Ultimatum Bargaining Games. Wasilios Hariskos, *Max Planck Institute for Human Development Berlin, Germany*, Konstantinos Katsikopoulos, *Max Planck Institute for Human Development Berlin, Germany*, Gerd Gigerenzer, *Max Planck Institute for Human Development Berlin, Germany*. We investigate how well a formalized heuristics model predicts outcomes of one-shot ultimatum bargaining experiments in comparison to inequality aversion models, namely: a subgame perfect equilibrium model with heterogeneous Fehr-Schmidt preferences, a

quantal response equilibrium model with Fehr-Schmidt preferences and quantal response equilibrium model with ERC preferences. We fit the models to experimental data from a two-person ultimatum game and assess how well they predict outcomes of a three-person ultimatum game. Our results show that the heuristics model is not worse in fitting the outcomes of the two-person ultimatum experiment and better than any inequality aversion model in predicting the outcomes of the three-person ultimatum experiment.

Monday, 5:00
Fechner

Better safe than sorry: When superstition pays. Shunan Zhang, *University of California, San Diego, United States of America*, Angela J. Yu, *University of California, San Diego, United States of America*. People exhibit an automatic sequential effect in many behavioral tasks: they respond more rapidly and accurately to stimuli that reinforce a local pattern in stimulus history compared to when they violate such a pattern. For example, in a two-alternative forced choice (TAFC) task, despite a randomized design that deliberately de-correlate stimuli from trial to trial, subjects pick up transient sequences of repetitions and alternations; their responses are facilitated when a stimulus retains the pattern (e.g. AAAAA followed by A, ABABA followed by B), and are impeded when the stimulus violates the pattern (e.g. AAAAA followed by B, ABABA followed by A). Sequential effect is suboptimal in the context of randomized design, where the local patterns arise merely by chance, thus the stimulus history has no real predictive power.Yu and Cohen (2009) provided a normative Bayesian model of the sequential effect, known as the dynamic belief model (DBM), as a reflection of the adaptative learning of a changing environment. They showed that non-stationary prior belief can induce observed sequential effects in experiments, while using an otherwise Bayes-optimal algorithm.In this study, we examine the explicit consequence of a non-stationary beliefs on discrimination reaction time and accuracy in a 2-alternative forced choice task. We model the relationship between a biased prior about stimulus type, generated by DBM, and speed/accuracy using a well-studied perceptual decision model, the drift-diffusion model (DDM). We jointly estimate the parameters for DBM and DDM in order to account for subjects' behavioral data, and show that the joint model provides a sensible account of the sequential effect in the 2AFC task. Our results explain why sequential effects may persist in truly stationary (and random) environments: the large behavioral benefit of being able to extract statistical patterns outweighs the relatively small cost of latching onto chance coincidences.

Monday, 5:20
Fechner

On Relations among Decision Rules for the Same-different Task. Lawrence T. DeCarlo, *Teachers College, Columbia University, United States of America*. If one makes a same-different decision by making separate covert decisions with a fixed criterion location (or with two fixed criteria), then the resulting ROC curves are improper (Egan, 1975) in that they do not have monotonically decreasing slopes and do not pass through the point (1,1). Here it is shown that proper ROC curves result if the criterion location for the second decision depends on the first

decision. The result is direct bias towards a response of "same" or "different". An additional consequence is that, even though the observations are independent, the decisions are correlated. Another approach to the same-different task is to use a decision rule where the perceptions are "differenced". It can be shown that this approach is equivalent to yet another approach, which is to use a mental "yardstick" in the original (non-differenced) decision space. Although the "differencing" and "yardstick" decision rules are mathematically equivalent, they differ with respect to assumptions about underlying decision processes. For example, the differencing approach implies the existence of a unit in the decision rule, so that the differencing operation is meaningful, whereas the yardstick approach only involves an ordinal decision of "greater than" or "less than" (a quantitative aspect, in terms of additivity, arises at the structural level instead of at the decision level). Further study of decision rules in the same-different task is needed, along with study of situations that involve more than two alternatives and that vary the task.

Learning

Chair: Jessica B. Hamrick

Tuesday, 8:40
Euler

Modelling active causal learning. Neil Robert Bramley, *University College London, United Kingdom*, David Lagnado, *University College London, United Kingdom*, Maarten Speekenbrink, *University College London, United Kingdom*. Existing studies on causal structure learning are largely restricted to single-shot interventions, usually in constrained or deterministic scenarios. However, real world causal learning is generally noisy, incremental and constrained only by prior beliefs. Here we describe experiments where participants were incentivised to infer the causal structure of a series of novel noisy systems of nodes through the free selection of multiple interventions. Participants' sequences of intervention choices and online structure judgements are measured against those of an efficient Bayesian learning model, which integrates information perfectly and intervenes to maximise expected utility. Successful participants learned effectively, but chose systematically different intervention sequences to those of the Bayesian learning model. This is not surprising as the processing requirements of calculating expectancies over multiple hypotheses, interventions and time points are considerable and scale exponentially. However, several simple active learning models were motivated by these patterns. These models were heuristic in flavour, and provided a good fit with participants' actions and structure judgements as well as generating several of the typical attribution biases found in the causal judgement literature. Overall, we find evidence suggesting that causal structure learning is achieved through simple, action-selection and causal-attribution mechanisms.

Tuesday, 9:00
Euler

Comparing two classes of formal models of learning in probabilistic decision making. Marc Jekel, *University of Göttingen, Germany*, Andreas Glöckner, *University of Göttingen, Germany; MPI Collective Goods*, Arndt Bröder, *University of Mannheim*. A key aspect of making good decisions is accurate learning of cue-criterion relations in

probabilistic environments. Elaborating on previous work on a formalized parallel-constraints satisfaction network model of decision making (PCS), a learning mechanism for PCS based on a modified algorithm of backward error-propagation was compared to the reinforcement learning theory of strategy selection for fast and frugal heuristics (SSL). In our study, participants were asked to decide which of two stocks in a market game is more profitable. In each trial, experts were presented who either speak for or against the stocks. The experts suggested the more profitable stock with an unknown probability. After each trial, participants received feedback on the accuracy of their decision and thus also on the accuracy of the experts. Over all trials, the stock was reinforced with the higher probability for profitability in accordance with the nave Bayesian computation of expert opinions. Results show that people are able to approximate the rational solution for different probabilistic environments quite well. A model comparison based on predicted choice probabilities also shows that PCS can account for the data better than SSL.

Tuesday, 9:20

Euler

The myth of cognitive decline. Michael J. A. Ramscar, *Tübingen University, Germany*, Peter Hendrix, *Tübingen University, Germany*, Cyrus Shaoul, *Tübingen University, Germany*, Harald Baayen, *Tübingen University, Germany*. As adults' age increases, their reaction times slow across a range of psychometric tests. This change has been widely taken to show that cognitive information-processing capacities decline steadily throughout adulthood. Contrary to this, we suggest that these slower responses are not indicative of processing deficits, but instead reflect a search problem, which escalates as learning increases the amount of information in memory. A series of analyses and simulations show how age-related slowing is a natural product of learning, and emerges naturally in learning models, suggesting that the pattern of slowing observed in many tasks simply reflects the statistical properties that typify much of human experience, and the increased information-processing load that a lifetime of learning from this experience inevitably brings. Further analyses show how many of the changes in paired associate learning performance and name retrieval usually attributed to processing declines are simply a function of learning from the skewed distributions that typify natural languages. Once the cost of processing the extra information that comes with this learning is controlled for, findings taken to indicate declines in cognitive capacity can be seen to support little more than the unsurprising idea that choosing between or recalling items becomes more difficult as their numbers increase. We review the implications of this for scientific and cultural understanding of aging.

Tuesday, 9:40

Euler

Inferring mass in complex physical scenes via probabilistic simulation. Jessica B. Hamrick, *University of California, Berkeley*, Peter W. Battaglia, *Massachusetts Institute of Technology*, Thomas L. Griffiths, *University of California, Berkeley*, Joshua B. Tenenbaum, *Massachusetts Institute of Technology*. How do people learn about underlying physical parameters, such as mass and friction, from the interactions of objects in complex, dy-

namical scenes? Discovering the values of such properties is a difficult task: the parameters cannot be observed directly, and their influence on the sequence of dynamics is often complicated and difficult to resolve unambiguously. Yet, people can do this. We showed participants towers of blocks stacked in complex configurations, and asked them to predict whether each tower would fall. After giving them the correct answer, we asked a further question: which blocks were heavier? With the correct information about stability, participants rapidly learned the blocks' relative masses. We propose that this learning can be viewed as probabilistic inference in a generative model that approximates Newtonian rigid-body dynamics. To express this hypothesis, we built a model that uses physical simulation and Monte Carlo sampling to predict what will happen and then to update its beliefs based on the divergence of its predictions from reality. Participants' judgments were qualitatively consistent with those of this physics-aware model observer, but also deviated in key ways that may be explained by information and resource limitations. This is an important step in understanding how people perceive and reason about the physical nature of their environment, and provides a working framework for modeling and testing people's inferences about unobserved properties in complex, real-world scenes.

Measurement Theory

Chair: Jean-Paul Doignon

Tuesday, 8:40

Fechner

Bayesian inferences for multidimensional scaling models. Michael D. Lee, *University of California Irvine, United States of America*, Geoffrey Iverson, *University of California Irvine, United States of America*, James Pooley, *University of California Irvine, United States of America*. Multidimensional scaling (MDS) models represent stimuli as points in geometric spaces, so that the distances between points relates to the psychological similarity of stimuli. We consider two of the most important MDS representational spaces for cognitive models, involving the Minkowskian city-block and Euclidean metrics, in terms of Bayesian inference from pair-wise similarity data. Building on the existing literature, the geometric transformations required for model identifiability are characterized, and new Bayesian methods using computational inference in graphical models are developed and applied to a number of seminal data sets. We discuss the potential advantages of this approach to Bayesian inference for MDS representations, including how they represent uncertainty, can accommodate individual differences, and allow for inferences about dimensionality.

Tuesday, 9:00

Fechner

An Extension Theorem and a Numerical Representation Theorem for Qualitative Comparative Expectations without an Archimedean Axiom, without Measurability or Closure Conditions, and without help from Ultraproducts. Arthur P. Pedersen, *Max Planck Institute for Human Development, Germany*. This is a contribution to measurement theory with a special focus on the foundations of decision theory, probability, and expectation. I extend and improve upon related theoretical developments, notable contributions of which

include (Scott, 1964), (Narens, 1974), and (Coletti, 1990) in JMP. I offer an account of expectation based on a *qualitative criterion of coherence* for *qualitative comparisons* of random quantities (RQs). This criterion is reminiscent of de Finetti's quantitative criterion of coherence. However, the criterion does not impose an archimedean condition on qualitative comparisons; it does not impose *transitivity,* *reflexivity,* or *completeness*; and the criterion respects the *principle of weak dominance,* which demands that a gamble judged never better than another gamble and sometimes worse ought to be rejected as inadmissible when the other gamble is available. Like de Finetti, I formulate the criterion for an arbitrary collection of RQs, but I do not require that they are *bounded.* I describe a theorem asserting that any coherent system of comparative expectations can be extended to a weakly ordered coherent system over any collection of RQs containing the initial set of RQs. I also explain a representation theorem asserting that any weakly ordered coherent system of comparative expectations over a linear space can be represented by an expectation function taking values in an ordered field extension of the real numbers. I use the *Hahn Embedding Theorem* to obtain the ordered field, elements of which are *formal power series* in a *single* infinitesimal, enabling infinitely large differences in expectations of RQs to be *traced* to infinitely large differences in qualitative comparisons. Finally, I describe an account of nonarchimedean expected utility in the style of Anscombe and Aumann.

Tuesday, 9:20

Fechner

The Semiorder Polytope. Selim Rexhep, *Université Libre de Bruxelles, Belgium.* Random utility models are widely used in mathematical psychology. In such a model, a set of possible alternatives is given, and one is searching for a numerical representation of the fact that choice a is preferred to choice b. A given choice is typically modeled by a random variable, representing its "utility". Several authors (Block and Marschkak, Falmagne, Koppen) have shown that dealing with such random variables can be reduced to studying some probability distributions defined on the set of linear orders of the alternatives.In particular, they have shown that the problem can be solved by finding the facial structure of the linear order polytope (obtained by tacking the convex hull of all the characteristic vectors of linear orders on the set of alternatives). Since then, many generalization of this viewpoint (obtained by replacing the class of linear orders by other classes of relations) has been studied (Suck, Heyer and Niedere). In particular, semiorders are quite useful in these models.Our goal here is to present a first study of the facial structure of the semiorder polytope. We give a rather large class of facet defining inequalities for this polytope, containing in particular the well known n-fence inequalities of the linear order polytope.

Tuesday, 9:40

Fechner

Chains of biorders, interval orders or semiorders. Jean-Paul Doignon, *Université Libre de Bruxelles, Belgium.* Biorders, interval orders and semiorders are

three types of relations which today have gained the status of classical concepts. They are used for various purposes, for instance biorders capture Guttman scaling, while interval orders and semiorders serve to model preferences of individuals. In our eyes, the main feature of each of these three types of relations lies in the rather simple set of axioms ensuring the existence of numerical representations of a specific form.Here we consider a chain of relations, all being simultaneously of one of the three types. Our aim is to establish conditions for the existence of numerical representations for the individual relations which altogether reflect the inclusions among the relations in the chain. In the finite case, it curiously happens that the necessary and sufficient conditions consist only of the classical axioms stated for any of the relations. Even more intriguing is the method of proof, which exploits the well-gradedness of the collection of relations of a given type. As surprising byproducts, we derive (apparently new) proofs for the classical representation theorems of a single relation. Unfortunately, the method does not apply to the infinite case—at least not in a way obvious to us at the present time. The results are taken from joint work with Denis Bouyssou (CNRS, LAMSADE) and Thierry Marchant (Ghent University).

Decision Making 3

Chair: Konstantinos Katsikopoulos

Tuesday, 10:30
Euler

A Dynamic Dual-Process Model of Risky Decision-Making. Jennifer S Trueblood, *University of California, Irvine, United States of America.* Dual-process theory postulates that there are two fundamentally different systems that can process information. One system is described as automatic, intuitive, fast, and experiential. The other is labeled as deliberative, analytical, slow, and rational. Research has shown that dual-process accounts are often more successful at explaining behavioral phenomena than unitary approaches (Hogarth, 2001; Kahneman, 2003; Sanfey, Loewenstein, McClure, Cohen, et al., 2006). There is also evidence from the neuroscience community for two separable systems in the brain that contribute to decision-making (Damasio, 1994; Sanfey et al., 2006). However, existing dynamic models of decision-making assume that a unitary system is responsible for forming preferences. The current work introduces the first dynamic dual-process model of decision-making that can account for choice, response times, and prices. The Dynamic Dual-Process (DDP) model synthesizes ideas from several lines of research in decision-making and cognitive modeling. DDP draws upon the static Dual System Model developed by Mukherjee (2010) to explain how dual systems of reasoning evaluate options. DDP formalizes the formation of preferences as an accumulation of information over time similar to other dynamic models such as Decision Field Theory (Busemeyer & Townsend, 1993). DDP also employs a Markov chain model to account for pricing elicitation methods as in Busemeyer and Goldstein (1992) and Johnson and Busemeyer (2005). The model is applied to several phenomena from the risky decision-making literature including enhancements in preference by small losses, preference reversals due to response mode, and the influence of price and affect on preference.

Tuesday, 10:50

Euler

A Weighted Sequential Sampling Model of Risky Decision Making. Matthew D. Zeigenfuse, *Unversität Zürich, Switzerland*. Descriptive models of risky decision making typically model participants' preferences among risky gambles by combining a model of gamble valuation, like rank-dependent utility theory, with Luce's choice axiom. This approach ignores the information contained in their response times (RTs), so in many experimental applications sequential sampling models of decision making, such as decision field theory, are employed. Sequential sampling models, however, do not explicitly model gamble valuation, making it difficult to assess the relationship between the two types of models. Here I develop a sequential sampling model for decisions between two gambles that explicitly incorporates theories of gamble valuation. I also show that this model is not simply scalable, and that choice probabilities depends on all moments of the distribution of differences between the two alternatives. Finally, I derive choice and RT distributions and use these to investigate differences in how gamble valuation and decision rules affect choices and RTs.

Tuesday, 11:10

Euler

A Model of Positive Sequential Dependencies in Judgments of Frequency. Jeffrey Annis, *University of South Florida, United States of America*, Kenneth J. Malmberg, *University of South Florida, United States of America*. Over a series of decisions, positive sequential dependencies occur when the current response, n, is positively correlated with subsequent responses. These correlations are observed in a variety tasks, including Judgments of Frequency (JOF, Malmberg & Annis, 2011). Here we present a process model of JOFs that produces positive sequential dependencies within the REM framework (Shiffrin & Steyvers, 1997). The critical assumption is that features that represent the current test item in a retrieval cue carry over from the previous retrieval cue, and we assessed the sufficiency and the necessity of this assumption in several ways using newly collected data that distinguishes between the number of times two given items were studied (frequency similarity) and the similarity between stimuli (item similarity), which was varied by presenting either landscape photos (high similarity), or photos of everyday objects such as shoes, cars, etc (low similarity). Two models of item similarity were tested by assuming that the item representations share a proportion of features and that the exemplars from different stimulus classes vary in the distinctiveness or diagnosticity. A comprehensive exploration of several variants of these models suggests the plausibility of the basic model.

Tuesday, 11:30

Euler

Discriminating Among Probability Weighting Functions Using Adaptive Design Optimization. Daniel R. Cavagnaro, *California State University Fullerton*, Mark A. Pitt, *The Ohio State University*, Richard Gonzalez, *University of Michigan*, Jay I. Myung, *The Ohio State University*. Probability weighting functions relate objective probabilities and their subjective weights, and play a central role

in modeling choices under risk within cumulative prospect theory (CPT). The accuracy of CPT's predictions depend on the precision to which probability weights can be estimated, which in turn depends on specific assumptions about the parametric form of the probability weighting function. While several forms have been proposed, their qualitative similarities make it challenging to discriminate among them empirically. We use both simulation and choice experiments to investigate the extent to which different parametric forms can be discriminated using adaptive design optimization (ADO), a computer-based methodology that identifies and exploits model differences for the purpose of model discrimination. The simulation experiments show that the correct (data generating) form can be conclusively discriminated from its competitors. The results of an empirical experiment reveal heterogeneity between participants in terms of the functional form, with two models (Prelec-2, Linear in Log Odds) emerging as the most common best-fitting models. The findings shed light on assumptions underlying these models.

Tuesday, 11:50

Euler

Decreasing bounds in sequential decision-making. Gaurav Malhotra, *University of Bristol, United Kingdom*, David Leslie, *University of Bristol, United Kingdom*, Rafal Bogacz, *University of Bristol, United Kingdom*. A popular class of models for studying the dynamics of perceptual decision-making are the rise-to-threshold models. These models assume that individuals make perceptual decisions by accumulating information from the environment till it reaches a certain bound. Recently, there has been a lot of interest in the nature of these bounds, specifically, whether these bounds are constant or do they change with time and based on the information that the individual is getting. We investigated this question from both a theoretical and empirical point of view. First, we developed a mathematical model for the optimal shape of bounds under the scenario where individuals have to make sequential decisions on perceptual stimuli that could have one of two different coherences. In agreement with a previous model, our model showed that the optimal bound in this scenario is not constant but decreases with time. We then tested the behaviour of human subjects under the scenario that parallels the assumptions of the theoretical model. We found that, in agreement with the optimal model, individuals showed decreasing bounds in the condition where they did not know the coherence of incoming information ahead of time. In contrast, when they know the rate of incoming information ahead of time, their bounds remained constant. Our research teases apart how individuals use information in the environment to make decisions and paves the way for a mechanistic model of perceptual decision-making in an uncertain environment.

Tuesday, 12:10

Euler

QTest: Quantitative Testing of Theories of Binary Choice made accessible. Michel Regenwetter, *University of Illinois at Urbana-Champaign, United States of America*, Clintin P. Davis-Stober, *University of Missouri at Columbia, United States of America*, Shiau Hong Lim, *National University of Singapore, Singapore*, Ying Guo, *University*

of Illinois at Urbana-Champaign, United States of America, Anna Popova, *University of Illinois at Urbana-Champaign, United States of America*. Behavioral decision researchers need accessible mathematical, statistical, and software tools that serve as a bridge between static algebraic decision theory and observed variability in behavioral choice data. We provide a state-of-the-art probabilistic modeling framework and public-domain statistical analysis package. The QTest software is geared towards testing algebraic theories of pairwise preference on binary choice data. The program and its Graphical User Interface are specifically designed to make modeling and quantitative testing more accessible to behavioral decision researchers interested in substantive questions. We discuss different kinds of probabilistic specifications, many of which are ready to use across a broad range of algebraic theories, including numerical and heuristic models of pairwise preference. We illustrate the package with a quantitative analysis using published laboratory data, including tests of novel versions of "Random Cumulative Prospect Theory." A major asset of the approach is the potential to distinguish decision makers who have a fixed preference and commit errors in observed choices from decision makers who waver in their preferences.

Knowledge Space Theory

Chair: Jürgen Heller

Tuesday, 10:30
Fechner

Extracting a skill map from a data set: a KS construction methodology. Andrea Spoto, *University of Padua, Italy*, Luca Stefanutti, *University of Padua, Italy*, Giulio Vidotto, *University of Padua, Italy*. One of the core issues in Knowledge Space Theory is the construction of knowledge structures. Three main areas are usually explored in addressing this task: the first one is the query to experts procedure; the second one is the skill maps approach; the third one is the data driven methodology. All of these approaches present both pros and cons. The expert query procedure aims at finding the states of a structure by identifying the entailments among sets of items. The algorithms created to this aim allow reducing the time required to complete the task; nonetheless, the procedure is still very time expensive, fatiguing and subject to possible errors of the experts. The skill map approach represents a second and appealing methodology to build structures. It is based on the possibility to assign to each item a subset of skills needed to master it. Starting from such assignment, it is possible to deduce what the knowledge states in the structure are. The third methodology refers to the generation of a structure starting from an empirical data set. All the data driven methods available can be subdivided into two main categories: Boolean analysis of questionnaires methods, aimed at building a surmise relation among the items of a questionnaire; direct derivation of structures from data. In general, from a cognitive perspective, the most important limitation of both query and data driven procedures is that they work at the items level, leaving out any information concerning the skills level.In this contribution we propose a method to derive a skill map from an empirical data set. The method consists in obtain a knowledge structure from data, and then derive the skill map corresponding to that structure. The methodology uses some

well known properties of knowledge structures such as the relation between union and intersection closed structures and the possibility to obtain a skill map form the elements of the basis of a knowledge space. A procedure is presented that (i) extracts an intersection-closed knowledge structure from data, and (ii) obtains the conjunctive skill map corresponding to the extracted knowledge structure.A simulation study and an application to real data were conducted to test the procedure. Results show that the procedure adequately performs in identifying the best fitting model according to the need of having the simplest possible model in terms of skills. Both pros and cons of the methodology are discussed.

Tuesday, 10:50

Fechner

Modeling Missing Data in Knowledge Space Theory. Debora de Chiusole, *Università degli studi di Padova, Italy*, Luca Stefanutti, *Università degli studi di Padova, Italy*, Pasquale Anselmi, *Università degli studi di Padova, Italy*, Egidio Robusto, *Università degli studi di Padova, Italy*. The basic local independence model (BLIM) is a probabilistic model, developed in knowledge space theory (KST), for the empirical validation of knowledge structures and for the probabilistic assessment of individual knowledge.Since the BLIM was introduced, several questions concerning its applicability have been answered. Nevertheless there are still some open questions. One of these questions regards how missing answers should be treated. In fact, the BLIM is useful just for complete data sets not containing missingness.In the present work, two extensions of the BLIM for missing data are proposed. The former, called ignorable missing BLIM (IMBLIM), is based on the assumptions that missing data does not depend on the knowledge state of a student. In practice, this assumption holds true whenever a missing answer is the consequence of not presenting an item to a student. This situation could happen, for example, in a computerized assessment in which the item parameter order is at random and with a time limit. In the latter, called Missing BLIM (MissBLIM), the missing answers are parameterized and considered as one of the observable outcomes of the response process, as well as wrong and correct responses. Furthermore, this model is based on the assumption that the missing answers depend on the knowledge state of a student. This situation holds true in those cases in which a student intentionally omits an item.These two models were tested by a simulation study and an empirical application. The aim of the simulations was to examine the behavior of the two models when they make either right or wrong assumptions about the process that generated the missingness. The aim of the empirical application was to apply the two models in a real context, when different types of missing answers can occur in the data.

Tuesday, 11:10

Fechner

An Evolving Computerized Adaptive Testing Procedure for Enhancing Individual Knowledge Assessment. Pasquale Anselmi, *University of Padua, Italy*, Egidio Robusto, *University of Padua, Italy*, Luca Stefanutti, *University of Padua, Italy*, Debora de Chiusole, *University of Padua, Italy*. Computerized adaptive testing (CAT) allows the recovery of the latent state of an individual by presenting him/her with

only a minimal number of items. Procedures for CAT have been proposed in cognitive diagnostic modeling and knowledge space theory, that are based on the DINA model and the BLIM, respectively. Accuracy (i.e., the distance between the uncovered state and the true state) and efficiency (i.e., the number of presented items) of these procedures depend on the availability of adequate information about the probability distribution of the latent states in the target population and the error probabilities of the items. However, this information might be missing in practical situations. An evolving CAT procedure is proposed, that accrues information from the individuals already assessed and uses it for enhancing the assessment of the following individuals. When assessing the former individuals, parameter values are used that assure the accuracy of the assessment (uniform initial distribution of latent states and large error probabilities, equal for all items). As the number of individuals assessed increases, the parameter values are updated in order to enhance efficiency while guarantying accuracy. Maximum-likelihood estimates of the parameters are computed on the partial response patterns that are adaptively obtained for each individual. Simulation studies show that, asymptotically, the parameter values of the evolving CAT approach the true parameters, and the performance of the evolving CAT approaches that of a benchmark CAT using the true parameters.

Tuesday, 11:30
Fechner

Cognitive Diagnostic Models and Knowledge Space Theory: The non-missing link. Luca Stefanutti, *Università degli Studi di Padova, Italy*, Jürgen Heller, *Fachbereich Psychologie, Eberhard-Karls-Universität Tübingen*, Egidio Robusto, *Università degli Studi di Padova, Italy*, Pasquale Anselmi, *Università degli Studi di Padova, Italy*. The talk explores the connections between cognitive diagnostic models (CDMs) and knowledge space theory (KST), two approaches to individual knowledge assessment that share an important feature. Instead of a dimensional representation based on numerical continua, both of them implement a discrete, non-numerical representation of individuals. It may thus come as a surprise that these two research strands developed in parallel quite independently.Connections between the two theories are exemplified by spelling out specific links between two fundamental probabilistic models in CDM, and an equally important probabilistic model in KST: The Deterministic Inputs Noisy AND-gate (DINA) and the Deterministic Inputs Noisy OR-gate (DINO) models on the part of CDM, and the CBLIM, a competence-based extension of the Basic Local Independence Model (BLIM), on the part of KST. Besides exploring common ground, the talk also points out potential benefits that may result from considering models of one area that do not have a counterpart yet in the other. Bridging the gap between CDM and KST seems to be a promising enterprise, which can contribute to facilitating communication between the two camps, and may lead to more rapid advances in both research areas.

Tuesday, 11:50
Fechner

A perspective on Item Response Theory and Rasch Models based on the most probable distribution method, maximum entropy

principle and statistical mechanics. Stefano Noventa, *University of Verona, Italy*, Luca Stefanutti, *University of Padova, Italy*, Giulio Vidotto, *University of Padova, Italy*. Item Response Theory (IRT, Lord & Novik, 1968) and Rasch Models (Rasch, 1960) are the most important methodological frameworks for assessment in psychological testing. A formal derivation of these models requires both assumptions on the item response function, like continuity, monotonicity, and asymptotical behavior, and general assumptions or criteria, like local stochastic independence, sufficiency of the statistics, specific objectivity, and the existence of a dense set of items (Fischer & Molenaar, 1995). A different derivation of logistic models can be given in light of the most probable distribution method (MPD, Huang, 1987). In particular, IRT logistic models have been derived as the distributions accounting for the maximum number of possible outcomes in a dichotomous test while introducing latent traits and item characteristics as constraints to the system (Noventa et al., in press). The MPD method can however be considered just an introductory approach to the more suitable and elegant framework of statistical mechanics and the principle of maximum entropy (Jaynes, 1957). In particular, under such a perspective logistic models are those describing an equilibrium solution accounting for the maximum lack of information, or maximum randomness in the system. Indeed, logistic function is the inverse parameter mapping for a Bernoulli distribution, and exponential families can be derived as the maximum entropy solution in presence of linear constraints on the expected value of their sufficient statistics. An extension to the polytomous case is given in light of the previous frameworks. Considerations are drawn to investigate possible implications on modeling construction and fundamental measurement properties under such a connection. References: Fischer, G. H., & Molenaar, I. W. (1995). *Rasch Models: foundations, recent developments, and applications.* New York: Springer-Verlag; Huang, K. (1987). *Statistical mechanics.* New York: John Wiley & Sons.Jaynes, E. T. (1957). Information theory and statistical mechanics. *The Physical Review, 106*(4), 620–630; Lord, F. M., & Novik, M. R. (1968). *Statistical theories of mental test scores.* London: Addison-Wesley Publishing Company; Noventa, S., Stefanutti, L., & Vidotto., G. (in press). An analysis of Item Response Theory and Rasch Models based on the most probable distribution method. *Psychometrika*; Rasch, G. (1960). *Probabilistic models for some intelligence and attainment tests.* Copenhagen: Nielsen & Lydiche.

Tuesday, 12:10

Fechner

On the identifiability of probabilistic models in competence-based knowledge space theory. Jürgen Heller, *University of Tübingen, Germany*, Luca Stefanutti, *University of Padova, Italy*, Egidio Robusto, *University of Padova, Italy*, Pasquale Anselmi, *University of Padova, Italy*. As an indispensable prerequisite for unambiguously assessing the state of knowledge of an individual, the (local) identifiability of probabilistic knowledge structures has received some attention recently. This talk extends results available for the basic local independence model (BLIM) to its competence-based extension (CBLIM). Non-identifiability is shown to be due to

quite independent properties of the underlying skill function (assigning subsets of skills to items, each of which is sufficient for solving them), which can be characterized through its associated problem function (specifying the items that can be solved within a subset of skills) on the one hand, and through structural aspects of the delineated knowledge structure on the other hand. Conditions warranting (local) identifiability are discussed.

Models of Physiological Data

Chair: Galina Ivanova

Tuesday, 1:50

Bayes

Simulating the N400 ERP component as semantic network error: Insights from a connectionist network model of semantic processing. Milena Rabovsky, *Humboldt-Universität zu Berlin, Germany*, Ken McRae, *University of Western Ontario, London, ON, Canada*. The N400 ERP component is widely used in research on language and semantic memory. Although the component's relation to semantic processing is well-established, the specific computational mechanisms underlying N400 generation are currently not clear (Kutas & Federmeier, 2011). We explored the mechanisms underlying the N400 by examining which parameters in a connectionist model of semantic processing most closely covary with N400 amplitudes. The model has 30 input units representing word form that map onto 2526 directly interconnected semantic feature units representing word meaning, according to semantic feature production norms. We simulated a number of N400 effects obtained in human empirical research: influences of semantic priming, lexical frequency, number of features (NOF; also possibly a proxy for concreteness), and repetition, as well as influences of frequency and NOF on repetition effects. Cross-entropy error values were consistently in the same direction as N400 amplitudes. Like N400 amplitudes, error values were larger for low frequency words, larger for words with many features, and decreased for semantically related target words as well as repeated words. Furthermore, the repetition-induced decrease was stronger for low frequency words, and for words with many semantic features. In contrast, there was less of a correspondence between total semantic activation and the N400. Like N400 amplitudes, activation was larger for words with many semantic features. However, activation also tended to increase with frequency, repetition and semantic priming which is opposite to well-established N400 results, and may be more in line with increased activation facilitating decisions in lexical and semantic tasks. Our results suggest an interesting relation between N400 amplitudes and error values in connectionist models of semantic processing. In psychological terms, error values in connectionist models have been conceptualized as implicit prediction error (McClelland, 1994), and we discuss the possibility that N400 amplitudes may reflect this implicit prediction error in semantic memory.

Tuesday, 2:10

Bayes

EEG-Coupling Analysis via Circular Correlation Coefficients? A Comparison with Conventional Methods. Katrin Pauen, *Department of Computer Science, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Ger-*

many, GALINA IVANOVA, *Department of Computer Science, Humboldt-Universität zu Berlin, Unter den Linden 6, 10099 Berlin, Germany*. In the recent years, several EEG studies have outlined the crucial role of signal phases for higher brain functions. In the process, two different phase relationships are of particular interest. On the one hand, a signal can be phase-locked to the onset of an external stimulus. On the other hand, two or more signals can be coupled in phase. The extent of phase locking is usually estimated by the phase locking index (PLI), while bivariate phase coupling is commonly quantified by the phase locking value (PLV). To even capture relationships between more than two signals, two multiple circular correlation coefficients have recently been introduced. Naturally, their simple counterparts may also be utilized to detect bivariate phase couplings. Thus, a set of six distinct measurements results that grasp similar phase associations and that can be applied to event-related potentials (ERPs) as well as to evoked and induced oscillations. To determine which measure is best suited for a particular application, differences and similarities between all measures have to be examined. To this end, their theoretical background is considered and they are applied to real EEG data as well as to simulated data sets replicating their specific characteristics. Indeed, all measurements can be embedded in a common mathematical concept from which some key properties are derived. While the PLI and the PLV just estimate the phase or rather the phase difference variability across trials, the circular correlation coefficients set the shared variance of two phases in relation to their individual variability. Therefore, only these coefficients are able to distinguish between individual phase locking and mutual phase coupling. In contrast, the PLV responds to both and draws near one even for independent data sets with small individual variances. Consequently, a combination of the PLI and a circular correlation measure is recommended whenever phase-locked signals, like ERPs and evoked oscillations, are considered. With this, a complete and unambiguous picture of all phase dependencies can be provided. Induced oscillations, whose phases vary from trial to trial, can be examined with the PLV or circular correlation measures. However, the use of circular coefficients is suggested as they are suitable to detect multiple phase couplings and since they can even be utilized in single trial analyses.

Tuesday, 2:30

Bayes

Cross-modal detection of task-unrelated thoughts using Hidden Markov Models. MATTHIAS MITTNER, *Universiteit van Amsterdam, The Netherlands*, WOUTER BOEKEL, *Universiteit van Amsterdam, The Netherlands*, ADRIENNE M. TUCKER, *Universiteit van Amsterdam, The Netherlands*, BIRTE U. FORSTMANN, *Universiteit van Amsterdam, The Netherlands*. Frequently, humans engage in task-unrelated processing, even under conditions of sustained attention (Smallwood, 2013). Estimates for the frequency of mind-wandering range from 40 to 50% of our waking time (Killingsworth & Gilbert, 2010). Obviously, such a high proportion of episodes of off-task cognition (task-unrelated thoughts, TUTs) poses a significant threat to the interpretation of many studies investigating cognitive functions. In addition, little is known about the nature of the underlying drifts in attention, e.g., whether they can be

conceptualized as binary states (dichotomy hypothesis; Smallwood et al., 2011) or whether it is more appropriate to treat the phenomenon as a continuum (levels of inattention; Schad, 2012). Task-unrelated thoughts (TUTs) have been empirically linked to increased activity in the default mode network (DMN; Christoff et al., 2009) as well as increases in alpha-power in the EEG (Mo et al., 2013) and eye-tracking measures (pupil diameter, Smallwood, 2011; blink-rate, Smilek et al., 2010; and saccades, Uzzaman et al., 2011). We implement a data-driven approach to estimate epochs of task-unrelatedness by fitting Hidden Markov Models (HMMs) to features from different modalities. The approach is tested on data from a Stop-Signal task (e.g., Forstmann et al., 2012) under simultaneous acquisition of fMRI and eye-tracking data. In addtion, we implemented a thought-sampling procedure at random points in the experiment similar to Christoff et al. (2009). This approach enables us to select features relevant for predicting off-task episodes using classifier-accuracy in a machine-learning approach. These features include single-trial estimates of DMN activity derived from functional magnetic resonance imaging (fMRI) data, instantaneous blink-rate, pupil-diameter, reaction times, and behavioral errors. By using appropriate emission probability distributions for the multi-modal data (e.g., the linear ballistic accumulator model for error and correct RTs), we are able to model the temporal structure of episodes of task-unrelated thoughts. By inferring the posterior state sequence, the distribution of dwelling times in the hidden states can be estimated which gives a statistical approach to extract durationand frequency of TUTs. In addition, by using model comparison techniques, we can obtain an optimal number of hidden states, implicitly testing the dichotomy- against the levels-of-inattention hypothesis.

Tuesday, 2:50

Bayes

Methodology for Adaptive Automatic Quantification of Brain Signals in the Time-Frequency Domain. René Heideklang, *Humboldt-Universität zu Berlin, Germany*, Galina Ivanova, *Humboldt-Universität zu Berlin, Germany*. Owing to the complexity of the human brain, the measured electrophysiological signals, such as the electroencephalogram (EEG) or magnetoencephalogram (MEG), exhibit considerable inter- and intra-individual variability. By now, time-frequency representations, e.g., the wavelet transform, are standard tools for the dynamic analysis of such brain signals. Yet, although these techniques allow for localized analyses in the time-frequency domain, the inherent signal variability calls for more adaptive strategies. The fact that even in a controlled experimental context, non-averaged single trial recordings rarely produce the expected patterns should be acknowledged and explicitly accounted for. Thus, there is a demand for flexible methods to yield high-level representations of brain signal measurements.We developed a novel technique to quantify the varying patterns in electrophysiological brain signals by adapting a flexible model to the time-frequency representations of the data. After successful model fitting, the resulting parameters not only quantify patterns of neural oscillation when their exact locations and shapes are a-priori unknown. The obtained parameter values also have a clear interpretation as a path of increased neural

activity through the time-frequency plane. Our modeling method is able to generate simple but more robust patterns, as well as increasingly flexible representations. This trade-off regarding the model order is supported by effective strategies for automatic initial parameter estimation and high-order model fitting by iterative refinement. Since the presented approach is a generic tool for the quantification of oscillatory signals, it has numerous beneficial applications. These include feature extraction for signal classification, e.g., outlier detection or clinical studies, unsupervised techniques to find hidden relationships between multiple signals, model averaging to bypass the smearing effect, de-noising and data compression. Furthermore, the developed novel technique has a strong potential to become a key element for automated signal analysis in the context of rich volumes of data sets.

Tuesday, 3:10

Bayes

Explicit and implicit measures of memory strength. Christoph Weidemann, *Swansea University, United Kingdom*, Michael Kahana, *University of Pennsylvania, USA* . Classification of stimuli into categories (such as "old" and "new"in tests of recognition memory) requires the mapping of continuous signals to discrete responses. Introspective judgements about a given choice response are regularly employed in research, legal, and clinical settings in an effort to measure the signal that is thought to be the basis of the classification decision. Correlations between introspective judgements and task performance suggest that such ratings often do convey information about internal states that arerelevant for a given task, but well-known limitations of introspection call the fidelity of this information into question. We investigated to what extent response times can reveal information usually assessed with explicit confidence ratings. We quantitatively compared response times to confidence ratings in their ability to qualify recognition memory decisions and found convergent results suggesting that much of the information from confidence ratings can be obtained from response times.

Tuesday, 3:30

Bayes

Analysis of Cognitive Evoked and Induced Potentials Based on Intrinsic Mode Decomposition. Galina Ivanova, *Department of Computer Science, Humboldt-Universität zu Berlin, Germany*, Irina Katsarska, *Department of Computer Science, Humboldt-Universität zu Berlin, Germany*. The acquired electrophysiological signals as neural correlates of information processes include three different time ranges starting with the application of the stimulus. These are referred to as the primary, secondary and tertiary phase. In the primary time region most components are predominantly related to the modalities of the exogenous stimulation, while in the secondary and tertiary regions the signal components are influenced by endogenous information processing. Although this could be seen as very general signal course differentiation, it could support the analysis and interpretation of the data. Considered from a signal processing point of view the acquired potentials consist of more or less strong deterministic evoked transient components or steady-state oscillations and additionally of non-phase locked induced oscillations. The possible occurrence and the characteristics

of all signal components depend on the construction of the stimulation paradigm.In this study we demonstrate that a modification of the proposed by N.E. Huang in 1996 decomposition, based on intrinsic mode functions and a consequent Hilbert transform, could significantly improve the signal component extraction of cognitive evoked and induced activities. The dynamic transitions between the different frequency bands can be explored and interpreted in a more suitable way than in case of conventional analysis, e.g., Fourier or Wavelet analysis. Furthermore we demonstrate the application of the above mentioned method for spatial analysis. Number of problems caused by the nature of the decomposition must be considered to accomplish different possible spatial solutions and also for the purposes of multi-trial analysis. The high dimensionality of the components and the inherent heuristics make this kind of analysis difficult. However in case of appropriate solution the results are of a quality which is not accessible with other complex established methods. The outcome of the methodology will be demonstrated based on the analysis of cognitive evoked and induced components which arise, e.g., during the application of an oddball paradigm. Finally further aspects for subsequent investigations will be discussed.

Perception and Signal Detection

Chair: Shenghua Luan

Tuesday, 1:50
Euler

Processing characteristics of monaural and binaural frequency perception: Extending systems factorial technology to auditory perception. Jennifer J. Lentz, *Indiana University, United States of America*, Yuan He, *Indiana University, United States of America*, Joseph W. Houpt, *Wright State University, United States of America*, James T. Townsend, *Indiana University, United States of America*. Systems factorial technology (SFT) was applied to the auditory modality to assess the various information processing characteristics of sounds with different frequencies. Stimuli were pure tones presented using a double-factorial design: each frequency (500 and 3020 Hz) was factorially combined with each intensity level (38 and 80 dB SPL). In a binaural condition, the 500-Hz tone was presented to one ear (randomly selected) and the 3020-Hz tone was presented to the other ear. In a monaural condition, both stimuli were presented to the same ear. Frequencies were selected to be greater than 2 octaves apart to limit tonotopic interactions within the peripheral and central auditory system. Experimental results suggest parallel architecture with a self-terminating stopping rule in both binaural and monaural conditions. Preliminary tests have found strong evidence of limited capacity in the later parts of the reaction time distribution and, pending further analysis, it looks as though some individuals evidence super capacity in their early reaction times. These

results extend the limited work evaluating architecture of the auditory system and confirm auditory models which treat different frequency channels as part of a parallel system for both monaural and binaural presentation. This study also demonstrates the extension of SFT to the auditory modality and provides a robust framework from which further studies of auditory system architecture can be developed.

Tuesday, 2:10

Euler

Suboptimal or just parsimonious? The specificity of learned expectations in motion perception. Kevin Lloyd, *University of Bristol, United Kingdom*, David Leslie, *University of Bristol, United Kingdom* . A body of work suggests that perception is well described as a process of Bayesian inference in which sensory information is combined with prior expectations to determine what is perceived. Previous work shows that such expectations or 'priors' can be learned quickly and automatically. For example, if participants are asked to estimate the direction of moving dots over trials in which some directions are more frequent than others, their estimates rapidly become biased towards the more frequent directions (Chalk, Seitz, & Series, 2010). A recent experiment explored the specificity of learned priors by presenting either red or green moving dots on each trial, with the direction of motion determined by distinct, colour-specific distributions (Gekas, Chalk, Seitz, & Series, 2013). In the initial experiment, rather than learning separate priors for each colour, participants' estimates were consistent with learning a single prior for stimuli of both colours. In a second experiment, manipulation of the colour-specific distributions led to at least some participants acting as if they had learned separate priors for the different colours. We employ Bayesian nonparametric estimation using Dirichlet process mixtures to explore the extent to which participants' behaviour is well described as the outcome of suboptimal Bayesian inference, as suggested by Gekas et al. In particular, we compare the performance of algorithms based on MCMC sampling and particle filtering to human performance, consider what the results tell us about perceptual inference, and derive novel predictions for future experimental verification.

Tuesday, 2:30

Euler

Continuous vs. Discrete Models of Signal Detection: An Exploration of the Subjective Uncertainty Area. Simone Malejka, *University of Mannheim*, Maarten Speekenbrink, *University College London*. Two measurement approaches compete for disentangling the cognitive processes involved in signal detection: continuous-strength models and discrete-state models. Continuous models (e.g., signal-detection theory) assume that subjective evidence strength varies along a single evidence dimension. In contrast, discrete-state models (e.g., the two high-threshold model) postulate finite detection and guessing states. Another difference between the rival approaches concerns whether, for a given subjective evidence strength, response decisions are deterministic or probabilistic. According to continuous models, "yes" responses are given whenever the subjective evidence is greater than a response criterion. In discrete models, sure "yes" and sure "no" responses are given when a detection threshold or a rejection threshold is crossed;

otherwise a response is guessed with a specific probability. Hence, the two thresholds enclose an area of subjective uncertainty on the objective evidence continuum. We propose that, in this region of uncertainty, the predictions of the competing models are most dissimilar and the models are thus most discriminable. Continuous models suggest monotonically decreasing and increasing response probabilities intersecting at the response criterion. Discrete models, however, propose step functions with lower response probabilities in the uncertainty area. To investigate the opposing predictions of both approaches, we (a) determined the bounds of the uncertainty area in a perceptual discrimination task and (b) investigated the relationship between evidence strength and response probability. Our results shed new light on the debate whether performance in signal-detection tasks should be analyzed assuming continuous vs.discrete subjective evidence strength.

Tuesday, 2:50
Euler

A Signal Detection Model of Advice Taking. SHENGHUA LUAN, *Max Planck Institute for Human Development, Germany*. When people make decisions on the basis of noisy information, advice from external sources can often help improve their performance. However, decision-makers (DMs) may face questions of when and from whom to get such advice, whether the advice is worth seeking given its cost, and how to combine the advice with their own observations. We use signal detection theory to develop a model of advice acquisition that enables formal definitions of these issues and prescribes optimal strategies for their solutions in the context of binary decisions. Our model draws on Fechner's idea of "interval of uncertainty" in perception and shares similarities with existing models of sequential sampling. Specifically, we assume a "consulting region" in the underlying observation scale of a DM and define the region by two offset parameters extending from the DM's decision criterion. A DM is assumed to seek advice whenever her observations fall in this region, whose size will depend on factors such as the accuracy and decision biases of the DM and the potential advisor(s), the cost of advice, and the particular consulting strategy adopted by the DM. Provided that the goal of a DM is to maximize expected earning (i.e., expected decision payoff minus advice cost), we derive the optimal sizes of the consulting region in different advice-taking scenarios. Following the model, we conducted three experiments with human participants. Our results show that (a) when consulting a single advisor, participants were sensitive to the cost and format of the advice (i.e., binary recommendations or continuous probability ratings) and were able to adjust the size of the consulting region accordingly; (b) when deciding between two advisors who differed in cost and accuracy but were equally helpful in improving their potential earnings, participants preferred the low-cost advisor to the high-accuracy one; and (c) facing two advisors with opposite decision tendencies—one tended to offer one type of binary advice (e.g., "buy stocks") while the other was the reverse (e.g., "not to buy")—most participants chose to consult the advisor whose advice was more likely to agree with their initial decisions. This resembles confirmation bias in hypothesis testing and is shown by our model as the optimal strategy in such advice-taking situations. These empirical results demonstrate

the usefulness of our model in explaining and improving our understanding of human advice-taking behavior.

Tuesday, 3:10
Euler

Reverse-engineering decision makers' priorities using signal detection theory and cultural consensus theory. Stefan M. Herzog, *Max Planck Institute for Human Development, Germany*. Decision makers often need to decide for or against an action in situations where there is an outside criterion to evaluate those decisions against (e.g., doctors decide whether or not to order a diagnostic test and evidence-based standards in medicine indicate whether a yes- or a no-decision is justified). Assuming symmetrical base rates, optimal observer models from signal detection theory prescribe that if decision makers value maximizing hits and minimizing misses, they should adopt a lenient response tendency (i.e., tendency to order the test). In contrast, if they value maximizing correct rejections and minimizing false alarms, they should adopt a conservative response tendency (i.e., tendency not order the test). These priorities (i.e., benefits of hits and costs of misses relative to benefits of correct rejections and costs of false positives) might not coincide with those of other stakeholders affected by such decisions (e.g., health authorities might prefer conservative testing, whereas doctors might prefer lenient testing to practice defensive medicine or to increase their income). When stakeholders probe decision makers' priorities, the latter sometimes cannot or are not willing to disclose their priorities. The current framework shows how one can reverse-engineer priorities using cognitive measurement models, thus connecting prescriptive and descriptive uses of signal detection models in decision analysis and cognitive science, respectively. Signal detection models allow decomposing the observed accuracy of a decision maker into competence (i.e., ability to discriminate between true yes- and true no-cases) and response tendency based on observing decisions and knowing the correct answers. Normatively, the response tendency should depend on the priorities, but also on the assumed base rate (i.e., the more yes-cases, the more lenient and vice versa). By using appropriate assumptions about base rate beliefs, decision makers' priorities can be reverse-engineered using the estimated response tendency. Models from cultural consensus theory allow estimating a decision maker's competence and response tendency even without knowing criterion values. I will discuss the two main challenges within this approach: How to handle (1) base rate beliefs and (2) multiple truths (recovered from cultural consensus analyses). To illustrate the framework, I will present analyses of synthetic and empirical data using hierarchical Bayesian estimation.

Tuesday, 3:30
Euler

Modeling Semantic and Orthographic Visual Priming. Brendan Johns, *Indiana University, United States of America*, Richard M. Shiffrin, *Indiana University, United States of America*. Eight non-diagnostic word primes were presented around the periphery of a three by three foveal square, and masked. Then a briefly presented and masked target word appeared in the center of the grid, and then two choices were presented. Primes were brief (not consciously perceived) or long, and either were neutral, or primed the target choice, the foil choice or both. Crossed with

these conditions, primes were identical to one of the choices, orthographically related to one of the choices, or semantically related to one of the choices (primes were chosen from the Deese-Roediger-McDermott false memory lists). Strong semantic and orthographic priming was observed, and interactions with prime duration suggested the operation of discounting (albeit of somewhat reduced magnitude), as incorporated in the ROUSE model applied many times by Huber, Shiffrin, Weidemann, and Denton. When both alternatives are primed, short priming improved performance and long priming reduced performance relative to the control condition. Such a finding required a modification of the ROUSE model. The modified model is fit to the results of three studies.

Memory Models 1

Chair: Elke Lange

Tuesday, 1:50

Fechner

Stimulus Similarity in Continuous Recognition Memory. Gregory Alexander, *University of California, Irvine, United States of America*, William Batchelder, *University of California, Irvine, United States of America*. What happens to the human memory of the image of a presented stimulus across time? A preliminary study in continuous recognition memory with picture stimuli has shown, as expected, that the hit rate for representing a previously presented stimulus does indeed decrease over lag. But what happens when a new similar stimulus is presented after some lag from an original presented stimulus? A natural assumption would be that if the similar stimulus was presented right after the presented stimulus, a subject would be exceptional at distinguishing the two from each other and avoid making a false alarm; however, if the similar stimulus was presented at some longer lag, the subject would have a harder time distinguishing between the two, resulting in an increase in false alarms due to confusion. Furthermore, when the lag between the presentation of the original stimulus and the similar stimulus is much longer, the subject would have a weaker memory of the original stimulus and this would result in fewer false alarms due to less confusion. Interestingly, this expected inverted-U false alarm function to new similar stimuli is what the current study has found. One explanation for the inverted-U is that the false alarm rate depends on two components. The first would be a the base rate for false alarm and the second component is confusion of the similar stimulus with the old stimulus given some lag. This paper will augment models in signal detection theory and high threshold theory to include processes that can handle the role of stimulus similarity and lag in continuous recognition memory studies.

Tuesday, 2:10

Fechner

MENS, an integrative model for the development of higher cognitive processes. André Ehresmann, *Université de Picardie Jules Verne, France* . Mathematical models in psychology are generally focused on particular cognitive processes. Are they common processes in brain dynamics allowing for the development of higher mental and cognitive processes such as learning, decision making, creative processes, etc. To study this problem we make use of the fol-

lowing neural properties: (i) a mental object activates a more or less distributed synchronous assembly of neurons; (ii) this assembly is not unique (Edelman's degeneracy of the neural code, 1989); (iii) the human neural cortex has a topologically central highly connected structural core shaping large scale dynamics (Hagmann et al., 2008). These properties are at the basis of the Memory Evolutive Neural Systems (MENS) which propose a formal integrative model of the functioning of the neural, mental and cognitive system. Based on Category Theory, MENS is an application of our Memory Evolutive Systems (Ehresmann & Vanbremeersch, 2007) which model self-organized multi-scale systems. MENS has a hierarchy of interactive components varying over time, which represent the neurons at the lowest level, and mental objects at higher levels. A mental object M is represented by a conceptual object ('symbol'), called a category-neuron, 'binding' (meaning it is the categorical "colimit" of) each synchronous assembly of neurons P which M can activate. Formally MENS is obtained by iterations of the "complexification process" (Ehresmann & Vanbremeersch, 1987) applied to the Evolutive System of Neurons. The main result singles out 2 properties allowing for the development of higher cognitive processes: (i) The Multiplicity Principle (MP), a kind of 'flexible redundancy' which extends the degeneracy of the neural code. MP makes possible the development of a long-term robust though flexible memory allowing for learning and adaptation, and the emergence of cognitive processes of increasing complexity. (ii) Formation of an Archetypal Core AC, generated by the structural core through complexifications. It acts as an internal model and a driving force for developing embodied cognition. Its strong connectivity and self-maintained activation allow for the formation of longer term "Global Workspaces" in which higher cognitive processes can develop through an iteration of: a retrospection process that recollects past information and makes sense of the present; and a prospection process that searches for more or less innovative procedures to respond to the situation.

Tuesday, 2:30

Fechner

Implementing a consolidation mechanism into SIMPLE.
Ullrich K. H. Ecker, *University of Western Australia*, Stephan Lewandowsky, *University of Western Australia; University of Bristol*, Gordon D. A. Brown, *University of Warwick*.
Empirically, memory for to-be-remembered material is impaired by interfering activity during the retention interval (e.g., study of a second study list). Impairment is largest if interfering activity immediately follows learning, and the bigger the temporal gap after learning, the smaller the impairment. Theoretically, there are at least two explanations for this temporal gradient. One popular notion is that memory traces require a process of post-encoding consolidation to be stabilized. Consolidation theory assumes the temporal gradient occurs because interfering material (e.g., list 2) interrupts consolidation (of list 1), and the longer the post-study gap, the more consolidation can take place. In contrast, Brown et al.'s (2007) SIMPLE model provides an alternative explanation in terms of temporal distinctiveness. Specifically, the discriminability of any two items (or lists of items) in memory will depend on relative time: the ratio

of the temporal distances of competing memory items at the time of retrieval. Items will be better remembered if they are temporally isolated during presentation. Thus the temporal gradient could emerge not because an increasing temporal gap allows for more consolidation, but because of the greater temporal distinctiveness conferred on the to-be-learned material. In a free-recall experiment, we examined the effects of rest periods (filled with an easy tone detection task) before and after study of to-be-remembered word lists. We manipulated the length of the intervals between the to-be-remembered list 1 and a retroactively interfering list 2 (i.e., the post-study interval), as well as the interval between list 2 and list 1 recall. We modeled the data within the SIMPLE framework, adding various possible implementations of a consolidation mechanism.

Tuesday, 2:50
Fechner

Information Accumulation for Recognition: Dynamic Presentation and Diagnosticity. Nicholas J. Lewis, *Indiana University, United States of America*, Gregory E. Cox, *Indiana University, United States of America*, Richard M. Shiffrin, *Indiana University, United States of America*. Cox and Shiffrin (2012) outlined a dynamic approach to recognition memory that suggests research directions that have thus far been lightly explored. For instance, what are the effects of manipulating the timing at which different kinds of information become available? And how does the salience and/or diagnosticity of that information affect subsequent recognition decisions? We report results from a set of experiments in which stimuli to be remembered are constructed from a set of discrete features (e.g., consonant triads or words) and, at test, the order in which the features appear is unconsciously manipulated (i.e., different letters come on at intervals of 33 ms). Contrary to the predictions of most models, both hit and correct rejection rates increase when diagnostic information comes on later, rather than earlier. These results are accounted for by a dynamic model of recognition, where the time at which information starts to be accumulated for a recognition decision can vary independently of when features are available to be sampled from the test display.

Tuesday, 3:10
Fechner

Response dynamics as a measure of bias and strength in recognition memory. Gregory J. Koop, *Syracuse University, United States of America*, Amy H. Criss, *Syracuse University, United States of America*. Models of recognition are evaluated by their ability to predict behavioral phenomena, typically gauged by performance metrics based on discrete choices (e.g., hits, false alarms, or other derivative measures). The mechanisms by which computational models produce these phenomena are designed to be psychologically plausible, but the reliance on accuracy data alone often makes it difficult to measure these processes. For example, explanations of the strength-based mirror effect positing either differentiation (e.g., Criss, 2006; 2009; 2010) or a metacognitive criterion shift (e.g., Stretch & Wixted, 1998; Starns et al, 2012) are unable to be discriminated based on discrete choice data. To help address this problem, we use continuous mouse tracking, or response dynamics. Response dynamics have seen very limited use in recognition memory (Papesh &

Goldinger, 2012) and their full potential as a metric with high process resolution has yet to be exploited. Over the course of four studies, we show that response dynamics can augment our current analytic repertoire in a way that speaks to the psychological processes underlying recognition. In two experiments, we manipulated encoding strength in yes/no (Expt 1) and 2AFC (Expt 2) recognition tasks. In two additional experiments, we manipulated the encoding strength and the ratio of targets on the test and either informed (Expt 3) or did not inform (Expt 4) participants about those changes in base rates. We found that the response dynamics measures of average absolute deviation (akin to area under the curve) and initial degree of departure showed substantial bias effects, both of which were enhanced in strong encoding conditions. This same pattern of data was present regardless of whether or not participants were informed about the underlying base rates. We conclude that response dynamics hold promise as a metric for evaluating the recognition process as it unfolds and as a tool for discriminating between models.

Tuesday, 3:30

Fechner

Perceptual Similarity, Encoding Strategy, and Decision Dynamics in Recognition Memory. Gregory E. Cox, *Indiana University, United States of America*, George Kachergis, *Indiana University, United States of America*, Richard M. Shiffrin, *Indiana University, United States of America*. In a series of recognition memory experiments, we manipulate the similarity among studied items and between targets and foils, as well as the value (positive or negative) assigned to each item. Stimuli are artificially constructed and have no prior preexperimental associations. These manipulations thus allow us to investigate the effects on recognition memory of pure perceptual similarity, and its interactions with encoding strategies induced by the value manipulation. We develop a stochastic signal detection model to explicate these effects, in which choice items are compared to noisy memory representations of the perceptual features each studied item, which are probabilistically associated with a particular value (positive/negative). Applying the model to our data, we find that increasing the number of similar study items leads to poorer encoding of the perceptual features of those items (i.e., a list homogeneity effect), as does blocked–as opposed to interleaved–study of similar items. Negative values are given greater weight at test and are more likely to be correctly encoded than positive values. Increased storage of negative value information comes at the cost of poorer encoding of the perceptual features of negative items. Finally, we relate the predictions of the model to the motor trajectories produced by participants at test, revealing the degree of accessibility of different kinds of information (perceptual features and value) at different times.

Categorization and Classification

Chair: Laura Felicia Martignon

Wednesday, 8:40

Bayes

Investigating the effects of subject covariates in multinomial processing tree models by recursive partitioning. Florian Wickelmaier, *University*

of Tübingen, Germany, ACHIM ZEILEIS, *University of Innsbruck, Austria*. Multinomial processing tree models are a class of statistical models for categorical data. The parameters of such models represent the probabilities of cognitive processing steps executed to arrive at observable response categories (Riefer & Batchelder, 1988). We introduce a first implementation of model-based recursive partitioning for multinomial processing tree models. Recursive partitioning can be used to investigate the effects of subject covariates and, in doing so, uncover individual differences in cognitive processes. The procedure is illustrated with examples from memory research.

Wednesday, 9:00

Bayes

Monitoring Clinical Treatment Response using Cognitive- and Statistical-Science Principled Measurement Technology. RICHARD W. J. (JIM) NEUFELD, *University of Western Ontario, Canada*. A mixture model architecture is brought to bear on cognitive-task performance entailing processes related to clinical symptomatology. Mixture-model base distributions of the mixture model are those of latency and/or accuracy, as stipulated by a tenable model of individual-participant cognitive performance; mixing distributions (hyper distributions; Bayesian priors) are those of individual differences in base-distribution –model parameters. Mixing distributions differ systematically across varyingly symptomatic and healthy groups, with respect to their mixing-distribution hyper-parameters. A sample of cognitive-performance data D from an individual client is combined with the hyper-distribution of a diagnostic group g to create a likelihood function of the performance data $LF(D|g)$. Implementing the relative density of the group amongst the individual's parent sample $Pr(g)$, a Bayesian posterior probability of "group membership", given the performance sample at hand becomes available – proportional to $Pr(g)LF(D|g)$. One such value can be computed for each of the G possible groups. The current individual thus is profiled with respect to probability of belonging to each of the respective groups. By sampling performance repeatedly over the course of treatment (possibly using parallel forms of the task, to address practice effects), a dynamical monitoring of treatment progress is available. The latter is estimated according to whether the individual is being edged closer to, or away from, healthy functioning– based on the moving profile of Bayesian posterior probabilities $Pr(g|D)$. After stipulating assumptions, the method is illustrated with data on memory-search probe encoding, a symptom-significant cognitive function in schizophrenia. Extensions include monitoring of treatment-regimen efficacy within the treated sample.

Wednesday, 9:20

Bayes

Causal-knowledge and Information Search During Categorization. JAY MARTIN, *New York University, United States of America*, BOB REHDER, *New York University, United States of America*. The effect of causal knowledge on classification is well established, but its role in information search is still largely unknown. This study assesses how causal knowledge influences the order in which classifiers seek information. Undergraduates learned two novel categories. One category's features exhibited a common

cause network (one feature causes two others), and the other exhibited a common effect network (one feature is caused by two others). One neutral dimension did not take part in any causal relations. Participants chose which of two feature dimensions they would like to see in order to classify an object. Participants preferred to query features involved in two causal relations over those involved in one, which in turn were preferred to those involved in none. In addition, when some features of the to-be-classified item were already known, participants chose to query causally-related dimensions in spite of the fact that there was no difference in the amount of information conveyed. Extended by sampling norms, existing models of causal-based classification failed to account for these results. We develop a theory that causal graphical models can mutate into undirected graphical models, or Markov random fields (MRFs), as reasoners may resort to a symmetric representation of causality for computationally intensive tasks.

Wednesday, 9:40

Bayes

Fast and frugal trees compared with Bayesian Networks. Laura Felicia Martignon, *PH Ludwigsburg, Germany*. Fast and frugal trees for classification and Bayesian Networks are two extremes of one spectrum: fast and frugal trees are simple classification strategies while Bayesian Networks for classification can become complex and even intractable depending on the size of data sets and the variables considered.We will prove theorems that characterize fast and frugal trees as lexicographic classifiers whose complexity is at most polynomial in the number of variables treated.We will compare the predictive accuracy of Bayesian Networks for classification with that of fast and frugal trees and point at situations that favor Bayesian Networks and situations that favor fast and frugal trees.

Reading and Word Processing

Chair: Reinhold Kliegl

Wednesday, 8:40

Euler

What's in a name? Engineering memorable names with the tools of information theory. Melody Dye, *Indiana University, United States of America*, Michael J. A. Ramscar, *University of Tuebingen, Germany*, Brendan Johns, *Indiana University, United States of America*. Human languages can be seen as socially evolved systems that are structured to optimize information flow in communication (Christiansen, 2013). One means of quantifying the rate of information transfer is through entropy, a measure of the amount of uncertainty a message contains at any given point (for example, how predictable a word is in a particular context). It appears that communication proceeds most smoothly when entropy is relatively stable: Peaks in entropy have been reliably associated with errors and delays in production on the part of the speaker, and difficulties in comprehension on the part of the listener. In previous work (Ramscar et al, in sub), we have examined how these constraints have shaped the evolution of naming practices historically, and how, over the last several hundred years, social legislation and rapid population growth have severely disrupted naming practices in the West, making West-

ern names harder to process and remember. In our current work, we are now testing these models empirically. The results of three studies, including a name generation task, name recognition test, and an artificial name learning experiment, provide converging evidence in support of information theoretic constraints on name memory. We discuss the social and cognitive import of these findings.

Wednesday, 9:00
Euler

Towards a Cognitive Bayesian Model of Word Learning. George Kachergis, *Leiden University, United States of America*, Shohei Hidaka, *School of Knowledge Science, Japan Advanced Institute of Science and Technology, Tsurugi, Japan.* Language learners may be able to figure out word-object mappings if they are able to correlate what they see and hear over time, assuming that caregivers sometimes refer to the environment. Such cross-situational learning may be important for the infant's developing lexicon, and has been the subject of several formal models that have focused on the problem at different levels. The computational-level Bayesian model proposed by Frank, Goodman, and Tenenbaum (2007) infers discrete word-object mappings in a principled way, but not in a cognitive way: learning is batch mode, and no cognitive processes are invoked. In contrast, Kachergis, Yu, and Shiffrin (2012) proposed an associative model with incremental learning, forgetting, and attentional biases. This heuristic model matches detailed behavioral data, but is derived from cognitive mechanisms rather than principled theoretical foundations. We present a series of Bayesian models that embody various cognitive principles, thus bridging the computational and algorithmic levels.

Wednesday, 9:20
Euler

The zoom lens of attention: Simulation of text reading using the SWIFT model. Daniel J. Schad, *Charité, Universitätsmedizin Berlin, Germany*. Assumptions on the allocation of attention during reading are crucial for theoretical models of eye guidance. The zoom lens model of attention postulates that attentional deployment can vary from a sharp focus to a broad window. The model is closely related to the foveal load hypothesis, i.e., the assumption that the perceptual span is modulated by the difficulty of the fixated word. However, these important theoretical concepts for cognitive research have not been tested quantitatively in eye movement models. Here we show that the zoom lens model, implemented in the SWIFT model of saccade generation, captures many important patterns of eye movements. We compared the model's performance to experimental data from normal and shuffled text reading. Our results demonstrate that the zoom lens of attention might be an important concept for eye movement control in reading.

Wednesday, 9:40
Euler

Are Parafoveal Effects of Word Frequency and Predictability due to Distributed Processing or Mislocated Fixations? Reinhold Kliegl, *University of Potsdam, Germany*, André Krügel, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*. Parafoveal effects of frequency

and predictability on fixation durations are theoretically controversial and empirically ambiguous. Theoretically, they are interpreted as evidence for distributed processing or saccadic error. Empirically, in German, both frequency and predictability effects of the fixated word are reported as negative, whereas those associated with the frequency and predictability of the upcoming word are negative and positive, respectively (e.g., Kliegl, 2007, JEPGen). We estimated the most likely fraction of mislocated fixations for every letter with a self-consistent iterative algorithm, relative to overall fixation landing-position distributions and word-selection probabilities (Krügel & Engbert, 2010, VisionRes), and compared frequency and predictability effects for observed and estimated ("corrected") fixation locations. There are two predictions: (1) If effects were due to mislocation, they should be reduced or eliminated after "correction" for mislocation. (2) If observed effects had "survived" despite mislocation of a proportion of fixations, they should be stronger for "corrected" than observed fixation locations. Results relating to effects of the fixated word and its left and right neighbor were maintained or stronger for corrected fixation locations, that is they were only in agreement with the second option. Therefore, it is highly unlikely that mislocated fixations are the sole source of parafoveal effects.

Memory Models 2

Chair: Pernille Hemmer

Wednesday, 8:40

Fechner

Rehearsal in working memory: Friend or enemy of retention? Stephan Lewandowsky, *University of Western Australia; University of Bristol*, Klaus Oberauer, *University of Zurich*. We examine the many explanatory roles that have been ascribed to various forms of rehearsal or refreshing in short-term and working memory paradigms. We instantiate the most common assumptions about rehearsal in generic simulations of decay and interference models, and we apply those models to benchmark paradigms ranging from immediate serial recall to complex span and delayed recall. The results show that articulatory forms of rehearsal can be harmful to memory performance in some circumstances, especially when combined with temporal decay. Rapid attentional refreshing performs considerably better, but so far there is scant empirical evidence that people engage in refreshing during short-term memory tasks. We conclude that a strong reliance on articulatory rehearsal as a causative agent in memory is unwise and that explanatory appeals to rehearsal are insufficient unless buttressed by precise modeling.

Wednesday, 9:00

Fechner

Bayes factors for multinomial processing trees. Eric-Jan Wagenmakers, *University of Amsterdam, Netherlands, The*, Joachim Vandekerckhove, *University of California at Irvine*, Dora Matzke, *University of Amsterdam,*

Netherlands, The. We present an importance sampling method to compute marginal likelihoods for multinomial processing tree (MPT) models. These marginal likelihoods can be used to quantify the evidence that the data provide for and against particular MPT models, regardless of whether or not the models are nested. We illustrate the method for a set of MPT models that embody different assumptions about the malleability of memory in eyewitness testimonies.

Wednesday, 9:20
Fechner

Discrete-Slots Models of Visual Working-Memory Response Times. Chris Donkin, *University of New South Wales, Australia*, Robert Nosofsky, *Indiana University*, Richard M. Shiffrin, *Indiana University*, Jason Gold, *Indiana University*. Much recent research has aimed to establish whether visual working memory (WM) is better characterized by a limited number of discrete all-or-none slots, or by a continuous sharing of memory resources. To date, however, researchers have not considered the response-time (RT) predictions of discrete-slots vs. shared-resources models. To complement the past research in this field, we formalize a family of mixed-state, discrete-slots models for explaining choice and RTs in tasks of visual WM change detection. In the tasks under investigation, a small set of visual items is presented, followed by a test item in one of the studied positions for which a change judgment must be made. According to the models, if the studied item in that position is retained in one of the discrete slots, then a memory-based evidence-accumulation process determines the choice and the RT; if the studied item in that position is missing, then a guessing-based accumulation process operates. Observed RT distributions are therefore theorized to arise as probabilistic mixtures of the memory-based and guessing distributions. We formalize an analogous set of continuous shared-resources models. The model classes are tested on individual subjects both with qualitative contrasts and quantitative fits to RT-distribution data. The discrete-slots models provide much better qualitative and quantitative accounts of the RT and choice data than do the shared-resources models, although there is some evidence for "slots plus resources" when memory set size is very small.

Wednesday, 9:40
Fechner

Modeling a non-monotonic relationship in single item recognition for continuous word frequency. Pernille Hemmer, *Rutgers University, United States of America*, Amy H. Criss, *Syracuse University, United States of America*. The word frequency mirror effect, higher hit rates and lower false alarm rates for low compared to high frequency words, is one of the hallmarks of recognition memory. However, this "regularity of memory" is limited because normative word frequency (WF) has been treated as discrete (low vs. high). We treat WF as a continuous variable and find a radically different pattern of performance. Hit rates show a clear non-monotonic U-shaped relationship. That is, hit rates are higher at both the high and low end of the frequency continuum. False alarm rates increase with increasing WF. The data will be explained within the framework of the Retrieving Effectively from Memory (REM) model. Until now predictions for REM have been based on treating low and high frequency

words as discrete categories, consistent with the empirical literature. Here we report simulations showing that REM predicts a complex pattern of performance across the range of WF values, a pattern that is qualitatively similar to the observed data. We discuss the constraints these data place on REM and other models of episodic memory.

Decision Making 4

Chair: Helen Steingroever

Wednesday, 11:30

Bayes

When two heads aren't better than one - the role of stimulus sensitivity and personality in joint decision making. Rebecca Floyd, *University of Bristol, United Kingdom*, David Leslie, *University of Bristol, United Kingdom*, Simon Farrell, *University of Bristol, United Kingdom*, Roland Baddeley, *University of Bristol, United Kingdom*. The adage "two heads are better than one" suggests that when two people discuss an ambiguous situation, the outcome of a joint decision will be closer to reality than each individual's evaluation. What is happening to the informational content of the discussion? Does precision increase and agreed answers migrate toward the more accurate of the pair? If not, what other factors might be influencing the decision? This study used a paradigm adapted from Bahrami et al (2010), where an ambiguous stimulus was presented to pairs of participants. We used random dot kinematograms in which 35% of the dots were travelling in a coherent direction. For each trial, participants individually indicated their perception of the direction of dot movement by manipulating a pointer on a circular dial, before then being shown each other's answers as a basis for discussing and agreeing a joint answer. At a broad level, the adage holds. On average, the joint answers were closer to correct than the answers of the individual participants. However, looking at pair-wise performance, the joint answers were often less accurate than those given by the more "sensitive" (i.e. more accurate) participant, especially when there was a large discrepancy in participant's abilities to detect dot direction. It appears that a weighting of individual estimates in the consensus decision reflects the precision of the initial estimates and we interpret these results in the context of a Bayesian model of how the participants combine their personal information. Deviations from "optimal" combinations are investigated alongside personality and dominance factors.

Wednesday, 11:50

Bayes

Evaluating Decision Maker "Type" Under p-additive Utility Representations. Nicholas R. Brown, *University of Missouri, United States of America*, Clintin P. Davis-Stober, *University of Missouri, United States of America*. Recent work by Luce (2010a; 2010b) on p-additive utility theory has yielded three distinct representation classes that correspond to risk attitude. We present a method for classifying decision makers under such p-additive model representations. Our approach extends the classification criterion described by Luce (2010b) to accommodate decision makers with risk attitudes that vary as a function of the decision environment. We present the results of a new decision making under risk experiment designed to evaluate risk attitude under p-additive utility

representations. We found that no single p-additive representation model emerged as the best description of the participants' preferences. Roughly half of the participants were best fit by models consisting of p-additive representations that vary as a function of the decision environment.

Wednesday, 12:10

Bayes

Assessing Goodness of Fit for Reinforcement-Learning Models of the Iowa Gambling Task. HELEN STEINGROEVER, *University of Amsterdam, Netherlands, The*, RUUD WETZELS, *The European Foundation for the Improvement of Living and Working Conditions, Dublin, Ireland*, ERIC-JAN WAGENMAKERS, *University of Amsterdam, Netherlands, The*. Decision-making deficits in clinical populations are often studied using the Iowa gambling task (IGT). Performance on the IGT can be decomposed in its constituent psychological processes by means of cognitive modeling analyses. However, conclusions about the hypothesized psychological processes are valid only if the model provides an adequate account of the data. In this presentation I emphasize the importance of assessing a model's absolute goodness of fit (GOF), and illustrate this general point with three IGT models: the Expectancy Valence (EV) model, the Prospect Valence Learning (PVL) model, and a hybrid model (i.e., the PVL model with Delta reinforcement-learning rule instead of the Decay reinforcement-learning rule). All models were fit to two stylized IGT data sets with prototypical choice patterns. The results revealed that neither the EV nor the PVL model provided a satisfactory fit to both data sets. This conclusion was confirmed by fitting the models to five published IGT data sets. However, the hybrid model provided a satisfactory fit to all data sets. Our results highlight that careful assessment of absolute GOF can prevent premature conclusions about the psychological processes that drive performance on the IGT.

Probabilistic Models

Chair: Niki Pfeifer

Wednesday, 11:30

Euler

Adaptive stopping in secretary problems with real values instead of ranks. JOHN WONG, *Max Planck Institute for Human Development, Berlin, Germany*, JONATHAN D. NELSON, *Max Planck Institute for Human Development, Berlin, Germany*, LAEL J. SCHOOLER, *Max Planck Institute for Human Development, Berlin, Germany*. The secretary problem involves choosing a candidate "secretary", where candidates are presented sequentially in random order for evaluation, and once a particular candidate is rejected, it is not possible to go back. A solution to the secretary problem is typically cast as an optimal stopping strategy. Studies (e.g., Seale & Rapoport, 1997, 2000) have found that people generally stop too early during search, and do not tend to get the best candidate. Gigerenzer and Todd (1999) proposed that stopping earlier than the optimal point for the highest chance to find the best applicant is actually a way of satisficing in cases where finding a candidate in the top 10 or top 25 percentile is good enough. However, these studies considered only the rank order of candidates' quality, whereas the real world typically involves real numbers, with

various distributions. We show via simulation that if the goal is to obtain the highest expected quality candidate, and real values of the underlying distribution of candidates are considered, that the optimal stopping point can be earlier than has been thought in previous research in this area. The optimal stopping point depends on the shape, and in particular on the skew and peakedness, of the underlying distribution of candidates' quality.

Wednesday, 11:50

Euler

Fuzzy control, dynamical traps and virtual stick balancing. ARKADY ZGONNIKOV, *University of Aizu, Japan*, IHOR LUBASHEVSKY, *University of Aizu, Japan*. In the present work we aim to shed light on some general properties of the human control behavior. We analyze probably the simplest example of a human-controlled process - inverted pendulum balancing. Human stick balancing has been investigated widely; however, up to now attention has been mainly paid to the in-depth understanding of the mechanical and physiological aspects of human control, such as response delay and noise. We propose a complementary approach and emphasize the existence and importance of some psychological issues as well. Imagine a dynamical system controlled by a human operator whose purpose is to stabilize the system near an equilibrium. We hypothesize that the operator does not react to small deviations of the current system state from the equilibrium, though these variations are clearly recognized by her perception. In other words, the operator perceives the desired end-state in a fuzzy way: she treats equally any point from a certain neighborhood of the equilibrium one.The presented results of the experiments on virtual stick balancing support our hypothesis. The angle distribution of the stick motion under human control takes the bimodal form with noticeable gap around the equilibrium. This confirms the assumption that small deviations are neglected by the operator. The angular velocity distribution is long tailed and best fitted by the Laplace distribution. Most interestingly, the found patterns of operator behavior remain the same for both the "slow" stick (when the task is easy and the operator acts in a relaxed manner) and the "fast" stick (when balancing requires full concentration and high skill).Finally, we develop the mathematical formalism capturing the fuzziness of human control. Building upon the concept of dynamical trap elaborated previously, we propose a stochastic model of human control, which is rather general and can be applied to a wide class of human-controlled systems. We demonstrate that our model (after being adapted to the specific process) produces practically the same patterns of behavior as the virtual stick under human control.The present work provides a strong evidence to the hypothesis that human control behavior in a whole class of dynamical processes is naturally fuzzy. Besides evident applications (such as human factors and ergonomics), the proposed stochastic model may prove useful in a wide class of processes under the scope of modern psychology and cognitive science.

Wednesday, 12:10

Euler

Mathematical philosophy meets mathematical psychology. NIKI PFEIFER, *Ludwig-Maximilians-University Munich, Germany*. Mathemat-

ical philosophy is characterized by using mathematical tools for philosophical analyses. Likewise, mathematical psychology uses mathematics for psychological model building and hypothesis formulation. In my talk I will discuss formal and empirical work on conditionals. Conditionals have a long tradition in philosophy and psychology and provide promising contact points where both disciplines can fruitfully interact.Specifically, I will propose coherence-based probability logic (CPL) as a rationality framework for investigating conditionals. I will discuss how CPL makes different psychological hypotheses about the interpretation of conditionals precise and how the different interpretations constrain the transmission of the uncertainty from the premises to the conclusion. Finally, I will illustrate my approach by the experiments I ran on Aristotle's theses and new data on the generalized probabilistic truth table task. These data shed new light on how people negate conditionals and on how people interpret conditionals in the context of incomplete probabilistic knowledge.

Dynamical Systems

Chair: Jerome R. Busemeyer

Wednesday, 11:30
Fechner

A Complex Dynamical Order Memory. Eva Cadez, *University of California, Merced, United States of America*, Evan Heit, *University of California, Merced, United States of America*. We treat memory as a complex dynamical system of individual memories that are more or less activated and interact with each other in numerous ways. For systems that change in time and whose current state depends on its own past state(s) and possible external influences, differential equations are the most frequently used tool in science and economy. We implement an equation whose use is widespread to describe how a single memory trace evolves in time and, in MATLAB, we simulate a complex system of memory traces. We have been able to obtain forgetting curves' shapes in these simulations and we are further exploring potential mechanisms of memory phenomena from this perspective. We also argue that order in time can be treated as order in space. We argue that it is necessary to have a distinct mechanism to keep track of order, especially for the beginning of episodes. We consider suggestions from cognitive linguistics about space-time interactions, as well as experimental evidence concerning the different behavior of memory for order of items and for items themselves. We show how our approach can easily implement this time-like dimension to obtain behaviors reported elsewhere in cognitive science. Finally, we compare our ideas to several other approaches and conclude that our perspective, as a complement, supports many ideas expressed elsewhere, but at a different level of explanation, and sheds significant new light on memory phenomena.

Wednesday, 11:50
Fechner

A mathematical model of group dynamics in social dilemmas. Arianna Dal Forno, *Department of Economics "Cognetti de Martiis", University of Torino*, Ugo Merlone, *Department of Psychology, University of Torino*. Social Dilemmas have been analyzed extensively in psychology. For example, Dawnes in his seminal paper (1980) surveyed the contributions of

psychologists who have studied dilemma behavior in the context of N-person games. Among social dilemmas, Braess paradox is an interesting example in which adding a further choice, when individuals behave rationally the outcome worsen. Using a mathematical formalization of social interaction grounded on individual behaviors we model the dynamics of choices. Specifically, we consider a heterogeneous population consisting of both agents with impulsive behavior and others whose decision making is related to the relative convenience of choices. We formalize the interaction as a discrete time dynamical system and analyze the dynamics of population. Our results show how the cycles caused by overshooting disappear when the proportion of impulsive agents decreases.

Wednesday, 12:10

Fechner

Decision Field Theory-Dynamic: A Cognitive Model of Planning On-The-Fly. Jared M. Hotaling, *Indiana University, United States of America*, Jerome R. Busemeyer, *Indiana University, United States of America*. Human are often faced with complex choices involving many interrelated decisions and events. In these situations achieving one's goals usually requires planning a sequence of actions, rather than a single decision. We present data collected in a dynamic decision making study in which individuals completed a series of multistage risky decisions represented as branching decision trees. At decision nodes, participants chose which path to take through the tree. At chance nodes, a marble was randomly drawn from an urn to determine the path. Each branch of the tree terminated with an outcome node signifying the number of points a participant could win. Several unique decision trees were created to represent various complex choice scenarios that individuals might experience in the world. We apply Decision Field Theory-Dynamic (DFT-D), a formal model of planning and multistage choice, to account for individuals' actions. DFT-D is based on the idea that people plan future choices on-the-fly, through quick, repeated mental simulations of potential future outcomes. Its mechanisms provide insight into how people collect and process information, and by fitting the model at the individual level we can begin to explain individual difference in these terms. DFT-D is compared to several simpler models that assume no mental simulation. We find, through model comparisons, that DFT-D provides the best account of individuals' behavior.

Decision Making 5

Chair: Konstantinos Tsetsos

Wednesday, 1:50

Bayes

Alternative Probability Theories for Decision Theory. Louis Narens, *UCI, United States of America*, . Two new kinds of probability theory have recently entered into psychology literature for modeling probability and decision judgments. One is based on ideas and methods that von Neumann developed for the foundation of quantum mechanics, and the other is based on a new interpretation of a logic developed for the foundations of mathematics by Brouwer and Heyting known as "intuitionistic logic". This lecture looks at how abstract concepts of "probability" restrict the form of their underlying logics, and use the result to provide insights for modeling decision making.

Wednesday, 2:10

Bayes

Modeling confidence: The puzzle of resolution. Rani Moran, *Tel-Aviv University, Israel*, Marius Usher, *Tel-Aviv University, Israel*, Andrei R. Teodorescu, *Tel-Aviv University, Israel*. Standard confidence judgment paradigms in decision-making feature four dependent variables: Decision accuracy, Decision RT, confidence and confidence RT. A vast manifold of relations between these measures is typically found in empirical data sets. One such empirical relationship, dubbed "resolution of confidence", corresponds to the higher confidence for correct than for error decisions. One puzzling aspect of this resolution is that it increases when decisions are made under time pressure. This finding has important implications for the question of whether confidence judgments are based on information that is available by the time the decision is made, as assumed by single stage models (e.g. balance of evidence), or is based on some additional post-decisional information, as assumed by two-stage models (e.g., 2DSD; Pleskac & Busemeyer, 2010). We examine this issue in the framework of absolute vs. relative models of sequential sampling (i.e. race models vs. the drift diffusion model). We present data that demonstrates (in support of 2DSD) that confidence is based on integration of additional information following the decision and that the post-decision time and the quality of the available extra information (following the decision) interact in determining confidence. Yet there are some challenging findings for the 2DSD model, such as: i) the improved resolution under time-pressure is not always correlated with increased inter-judgment times, ii) a negative correlation between confidence and inter-judgment times. We discuss implications with respect to models of decision-confidence.

Wednesday, 2:30

Bayes

Disentangling Decision Models: from Relative to Absolute Stopping Rules. Andrei R. Teodorescu, *Tel-Aviv University, Israel*, Rani Moran, *Tel-Aviv University, Israel*, Marius Usher, *Tel-Aviv University, Israel*. Sequential sampling models have played a paramount role in understanding the process of decision making. In such models, the evidence accumulation process is terminated by a stopping rule which determines when enough evidence has been accumulated for knowledgeable response. One way to implement this is to apply the stopping rule to the absolute level of activations. Under this assumption, the first accumulator to reach a predetermined amount of activation determines the response (and its latency). Independent Race and LCA models operate under this assumption. On the other hand, the stopping criterion can also be applied to some function of the relation between the absolute activations. For example, the response may be determined by the first accumulator to lead by more than a predetermined criterion, as in the classic diffusion model. Alternatively, the process can terminate as soon as the ratio between the activation of both accumulators exceeds a certain threshold (for example: when X1=1.5*X2). By definition, models implementing relative thresholds are invariant to input manipulations that do not affect the relative aspect of the evidence to which the stopping rule is applied (i.e. difference or ratio). Therefore, a manipulation that only

affects the absolute input level without altering its relative aspects could discriminate between relative threshold models, which would predict the null effect, and absolute threshold models, which would be sensitive to the overall increase in activation. We present an experimental paradigm which allows for the manipulation of absolute inputs while maintaining constant either their ratio (Multiplicative Boost condition - MB) or their difference (Additive Boost condition – AB) in a within block intermixed design. When compared to a Base Line (BL) condition, the results reveal a surprising sensitivity to the absolute input. Participants responded faster in both the MB and AB conditions compared to BL. In addition, accuracy was lower than BL in the AB condition but not in the MB condition. While absolute threshold models naturally account for these combined results, relative threshold models require additional assumptions. A revised diffusion model is developed which better accounts for the data by assuming that the level of internal processing noise is proportional to input strength. Implications for model architectures, model assumptions and different conclusions about the underlying cognitive mechanisms are discussed.

Wednesday, 2:50

Bayes

Comparing Perceptual and Preferential Decision Making. Gilles Dutilh, *University of Basel, Switzerland*, Jörg Rieskamp, *University of Basel, Switzerland*. In the decision making literature, there are two important domains of study that have developed largely in isolation. The one domain studies perceptual choice behavior, where the decision maker aims for a correct decision and there is an outside criterion that determines which decision is correct. The other domain studies preferential choice behavior, where the decision maker's goals are subjective, so that no correct option exists. Despite this difference between the two types of choice behavior and the relative isolation of the two domains, very similar sequential sampling models have been proposed to describe perceptual and preferential choice behavior. In this study we developed an experimental task that can be presented as either a perceptual or a preferential choice task. We show that this task elicits the classical phenomena of both types of decision making, including the speed-accuracy trade-off, risk seeking behavior and ambiguity aversion. Importantly, the task allows us to fit the same diffusion model to both perceptual and preferential choice data. This approach offers a formal way to explore both the differences and commonalities between the two types of decisions and it allows us to reveal the crucial processes that must be accounted for when modeling both perceptual and preferential choice.

Wednesday, 3:10

Bayes

Challenges for sequential sampling models: the influence of evidence variance on choices and choice response times. Konstantinos Tsetsos, *Oxford University, United Kingdom*, Christopher Summerfield, *Oxford University, United Kingdom*. Research on decision-making under conditions of uncertainty has converged to the notion that human observers sample and integrate multiple pieces of information towards a criterion in order to detect, discriminate or categorize ambiguous evidence. Linear models based on this integrate-to-threshold idea have been

successful in predicting several aspects of choice behavior (e.g. shape of reaction time distributions, relative latencies of correct and incorrect choices) and have found validation in a range of single-cell and human imaging studies. From these linear sequential sampling approaches, such as the diffusion or race model, two clear-cut qualitative predictions follow. First, in 2AFC tasks with interrogation (where the experimenter elicits a choice response at a specified time) choices between two options of equal mean but of differing variance are predicted to be at chance. Second, in single-stream categorization tasks with free-response protocol, streams of higher variance (i.e. lower reliability) are predicted to lead to more incorrect but also faster decisions. Here we present experimental evidence that violates these two predictions. First, participants performing 2AFC serial tasks showed a provariance bias, choosing more often the option with the higher noise. Second, decisions about the category identity of single streams of noisy evidence were more incorrect and slower for high-variance trials. Importantly, however, the response time effect interacted with the strength of evidence and in particular it disappeared for low mean trials. We account for these effects using a nonlinear version of the LCA model (Usher & McClelland, 2001), as well as a novel framework where the gain of evidence integration is quickly modulated by top-down expectations, dictated by the the thus far observed evidence.

Model Analysis and Comparison

Chair: Christian C. Luhmann

Wednesday, 1:50

Euler

Comparing Models of Probabilistic Conditional Reasoning: Evidence for an Influence of Form. Henrik Singmann, *Albert-Ludwigs-Universität Freiburg, Germany*, Karl Christoph Klauer, *Albert-Ludwigs-Universität Freiburg, Germany*, Sieghard Beller, *University of Paderborn, Germany*. According to popular probabilistic or Bayesian models of cognition (e.g., Oaksford & Chater, 2007; Griffiths, Chater, Kemp, Perfors, & Tenenbaum, 2010) responses in reasoning problems should reflect the probability of the conclusion given the information present in the premises based on participants' background knowledge of the problem. For example, Oaksford, Chater and Larkin (2000) propose a computational model of conditional reasoning performance according to which responses should correspond to the conditional probabilities of the conclusions given minor/categorical premise. In contrast, Klauer, Beller and Hüttner's (2010) dual-source model proposes that in addition to the information based on background knowledge, participants utilize information based on the form of the argument, conceptualized as the subjective probability with which a certain reasoning form is valid (e.g., "How valid is a Modus Ponens on a probability scale?"). Both types of information are then integrated by a weighting parameter. We fitted the model by Oaksford et al., the dual-source model, and a third model conceptualizing reasoning purely based on

background knowledge (via minimizing the Kullback-Leibler difference between prior and posterior joint probability distribution; Hartmann & Rafiee-Rad, under review) to six data sets (three data sets from Klauer et al. and three new data sets). Although the dual-source model had overall less parameters, it provided the best fits to all data sets lending support to the idea that humans integrate different types of information when reasoning and don't only use their background knowledge.

Monday, 5:40
Lobby

ANOVA Decomposition of Smoothing Splines. Hannes Matuschek, *University of Potsdam, Germany*, Reinhold Kliegl, *University of Potsdam, Germany*. Fixation durations in reading reflect effects of perceptual, language-related, and oculomotor conditions. Many of these effects are tied to continuous variables; often they are not linear and sometimes they are not even monotonic (e.g., the frequency effect of the fixated word). Generalized additive mixed models (GAMMs) allow for a flexible modeling of response surfaces. They incorporate splines (smooth functions) as fixed effects as well as random effects due to, e.g., subjects and words. Frequently, it is of interest whether a highly irregular response surface (e.g., the joint effect of the frequency of the current and the previous word) can be modeled as a simple addition of the two splines (i.e., main effects of the two frequencies) or whether the surface also requires their interaction. There is the option of a canonical decomposition (SS-ANOVA), typically implying a certain basis and penalty for the spline and therefore (possibly) ignoring prior knowledge about the data. We propose a new method that incorporates prior knowledge into the spline fit by performing the decomposition post-hoc. We showcase the performance of our method by crossvalidation on artificial data and with an analyses of the frequency effects on fixation durations during reading of the Potsdam Sentence Corpus.

Wednesday, 2:30
Euler

A flexible approach to simulating non-normal data using a non-linear structural model. Max Auerswald, *University of Mannheim, Germany*, Morten Moshagen, *University of Mannheim, Germany*. In robustness studies of statistical methods it is often desired to generate non-normally distributed data conforming to given covariance structures. This is not a trivial task, since non-normality transformations change the intercorrelations among the variables. A popular approach based on the power constants (Vale & Maurelli, 1983) allows for creating multivariate non-normal data by specifying values for skewness and kurtosis in certain bounds. However, distributions may differ considerably despite sharing the same values up to the fourth moment. We present a procedure for generating more severely non-normally distributed data based on a structural model with latent, manifest, and error variables. The latent variables are normally distributed and can therefore follow any covariance structure. The key idea is to create non-normality in the manifest variables by applying arbitrary (non-linear) linking functions to the latent and/or the error variables. The procedure corrects the weights to the manifest variables for the applied function f by the estimated correlation between a normally distributed variable Z and f(Z). The intercorrelations between the la-

tent variables, the weights of the errors, and the loadings are prespecified. The covariance matrix of the manifest variables is thus determined by this structure but is distorted by the potential distributional similarity or dissimilarity among the manifest variables. This deviation can also be estimated by Z and the covariance of f(Z), and is corrected by correlating the error terms accordingly. We used the MATLAB computing language to implement the algorithm. Simulation results showed that the root mean square error for the covariance matrix on the manifest level converges to zero with increasing sample size. Compared to the power constants procedure, the present approach is computationally less intensive and allows for more severe forms of non-normality affecting every moment. Thus, the results demonstrate the validity and utility of the approach to generate non-normal multivariate data. The procedure is easy to apply and useful for Monte Carlo simulations particularly in structural equation modeling.

Wednesday, 2:50

Euler

The flexibility of models of recognition memory: An analysis by the minimum-description length principle. David Kellen, *Albert-Ludwigs-Universität Freiburg, Germany*, Karl Christoph Klauer, *Albert-Ludwigs-Universität Freiburg, Germany*, Arndt Bröder, *University of Mannheim, Germany*. Model comparison in recognition memory has frequently relied on Receiver Operating Characteristics (ROC) data. One of the problems in the comparison between different candidate models is the need to quantify their ability to fit data in general. The purpose of this work is to bring model flexibility due to functional form into consideration by adopting model-selection indices based on the minimum-description-length (MDL) principle (for an introduction, see Grnwald, 2007). In the MDL framework, both models and data are understood as codes that can be compressed: The greater the compression, the better the account of the underlying regularities that are present in the data. The model with the shortest code is the one striking the optimal balance between fit and parsimony. One index that flows from the MDL principle is the normalized maximum-likelihood (NML) index, which quantifies a model's ability to fit any data pattern that could be observed in a given experiment. Model-recovery simulations show that NML outperforms other indices such as AIC and BIC. The NML index was estimated for a set of prominent discrete-state, continuous, and hybrid models of recognition memory, for the case of individual binary-response ROC data. In contrast with previous analyses solely based on goodness of fit, NML results for individual ROC data indicate a preference for a discrete-state model that assumes a mixture of detection and guessing states.

Wednesday, 3:10

Euler

The Predictive Accuracy of Intertemporal-Choice Models. Kodi B. Arfer, *Stony Brook University, United States of America*, Christian C. Luhmann, *Stony Brook University, United States of America*. How do people choose between smaller rewards available sooner and larger rewards available later? Past research has evaluated models of intertemporal choice according to goodness of fit or the qualitative ability

to accommodate specific decision-making anomalies. However, these criteria will tend to favor models that are flexible, and overfitting is an obvious danger. An alternative criterion for model quality is predictive validity. A psychological model's ability to accurately predict future behavior is of clear value, but is largely antithetical to the standard criteria for model evaluation. When predictive accuracy is being assessed, model flexibility is only valuable to the extent that it allows for superior prediction, and overfitting is properly penalized. In the current article, we compared four representative models of intertemporal choice, evaluating them on the basis of their predictive accuracy. The models included exponential discounting, generalized hyperbolic discounting, and two non-discounting, attribute-based choice models. Study 1 employed standard model evaluation criteria; parameter estimates and goodness of fit measures were derived from a single dataset. As expected, results favored the more complex models: the generalized hyperbolic discount model and the more complex attribute-based model. Study 2 assessed predictive accuracy by using separate datasets for the training and testing of models. The training sets were constructed adaptively to efficiently and precisely estimate model parameters for each subject. Results indicated that the generalized hyperbolic discounting model performed no better than the traditional exponential discounting model, and that the attribute-based models performed substantially worse than the discounting models. Our results support the enduring utility of discounting models, and illustrate the value of predictive accuracy as a criterion for model evaluation.

Accumulator and Diffusion Models

Chair: Andrew Heathcote

Wednesday, 1:50
Fechner

How Many Trials are Needed for a Robust Diffusion Model Analysis? A Comparison of Different Optimization Criteria for Parameter Estimation. Veronika Lerche, *Heidelberg University, Germany*, Andreas Voss, *Heidelberg University, Germany*. The diffusion model (Ratcliff, 1978) is a mathematical model for binary decision tasks. It belongs to the class of continuous sampling models and aims at providing information about ongoing cognitive processes. The degree of information utilization is generally high as both accuracy and response time distributions are considered. This allows the separation of various cognitive components (e.g., response criteria, speed of information uptake). These parameters can be estimated by the usage of different optimization criteria. In a series of simulation studies, we compare the accuracy of estimates for all parameters between three optimization criteria (Chi-Square, Maximum-Likelihood, and Kolmogorov-Smirnov). The simulated data differ in the number of trials and the number of stimulus types. Additionally, we test for robustness of the estimation procedures when data are contaminated by outliers. Results suggest that in contrast to current recommendations a reliable diffusion model analysis is possible under certain conditions even for small datasets with less than 100 trials.

Wednesday, 2:10
Fechner

An extensive comparison of probabilistic models on intertemporal choice. Junyi Dai, *Indiana University, Bloomington, United States of America*, Jerome R. Busemeyer, *Indiana University, Bloomington, United States of America*. Intertemporal choice has long been investigated from a delay discounting perspective which assumes a deterministic, alternative-wise and static view on the topic. Recent studies, however, have challenged this perspective. For example, Scholten and Read (2010) proposed an attribute-wise tradeoff model on intertemporal choice, which can account for intransitive choice patterns that elude the delay discounting approach. To further refine our understanding of intertemporal choice, we conducted a series of three experiments to explore its probabilistic and dynamic nature. All the results support the probabilistic hypothesis and therefore a variety of probabilistic models were developed to account for this important property. Specifically, we explored both alternative-wise models based on exponential and hyperbolic discounting functions and attribute-wise models based on direct and relative differences within attributes, as well as both dynamic models built upon decision field theory and static models with probit, logistic, and random preference choice rules. The dynamic models were fitted to both choice and response time data but the static ones were fitted to only choice data becasue they do not provide a description of response time. Finally, both identity and power utility functions were combined with other model components to generate the above models. The results of model comparisons using Bayesian Information Criterion suggest that in general dynamic models with direct differences and power utility functions perform the best in fitting both choice and response time data.

Wednesday, 2:30
Fechner

Bias in preferred initial direction of arm movements induces a decision bias. Jason Friedman, *Tel Aviv University, Israel; Macquarie University, Australia*, Matthew Finkbeiner, *Macquarie University, Australia*. When reaching to targets in front of the body in a speeded two alternative forced choice task, left-right biases have been observed in the initial heading direction. These tasks are often designed such that when the subject starts moving, they usually have not yet made their final decision. While these biases depend on experience with the task (e.g. if the right target is more likely to be correct, subjects will move more initially towards the right) and are a function of time (later movements are more likely to be towards one target or the other), the biases also differ across subjects. When the hand starts in front of the midline of the body (as in this experiment), the bias is usually towards the right, although the magnitude of this bias differs across subjects. In this experiment, we tested whether the extent of this bias (ratio of movements initially towards the left or right) affects the bias observed in the final decision.In this study, subjects reached out to targets on a touch screen in response to random dot kinematogram stimuli. Subjects were required to start moving within 350 ms. We observed that the amount of decision bias (quantified using signal detection theory) was correlated with the extent of the kinematic bias, even when the stim-

uli was completely uninformative. By fitting a Wiener diffusion model to features of the arm movement data, we show that this decision bias is manifested as the bias parameter in this form of model.

Wednesday, 2:50

Fechner

Action Video Games Do Not Improve the Speed of Information Processing in Simple Perceptual Tasks. Don van Ravenzwaaij, *University of Newcastle, Australia*. Previous research suggests that playing action video games improves performance on sensory, perceptual, and attentional tasks. For instance, Green, Pouget, and Bavelier (2010) used the diffusion model to decompose data from a motion detection task and estimate the contribution of several underlying psychological processes. Their analysis indicated that playing action video games leads to faster information processing, reduced response caution, and no difference in motor responding. Because perceptual learning is generally thought to be highly context-specific, this transfer from gaming is surprising and warrants replication in a large-scale training study. We conducted two experiments in which participants practiced either an action video game or a cognitive game in five separate, supervised sessions. Prior to each session and following the last session, participants performed a perceptual discrimination task. In our second experiment we included a third condition in which no video games were played at all. Behavioral data and diffusion model parameters showed similar practice effects for the action gamers, the cognitive gamers, and the non–gamers and suggest that, in contrast to earlier reports, playing action video games does not improve the speed of information processing in simple perceptual tasks.

Wednesday, 3:10

Fechner

Not all errors are equal: on the nature of slow and fast post-errors adjustments. Williams Paul, *University of Newcastle, Australia*, Andrew Heathcote, *University of Newcastle, Australia*, Lee Averell, *University of Newcastle, Australia*, Ami Eidels, *University of Newcastle, Australia*. In rapid response tasks, post-error adjustments refer to systematic changes in response time (RT) and accuracy following errors. Classically, the common finding of post-error slowing has been interpreted to suggest enhanced caution following an error (e.g., Laming, 1968; Rabbitt, 1966). Recently, however, challenges have arisen to the standard post-error theory (e.g., the orientation account, Notebaert et. al., 2009), and improvements have been proposed to the standard post-error measurement (e.g., the robust method, Dutilh et. al., 2012). We extend these efforts by employing a within subject speed and accuracy manipulation (n = 48) in recognition memory to examine post-error adjustments for comparable "fast-error" (speed) and "slow-error" (accuracy) tasks. We found that post-error slowing occurs under speed emphasis, and that post-error speeding occurs under accuracy emphasis. We also found that fast responses show more post-error slowing, and slow errors more post-error speeding. We discuss these results from the general perspective of evidence accumulation models of choice, and we provide a quantitative effect account in terms of the Linear Ballistic Accumulator (Brown & Heathcote, 2008).

Abstracts For Posters

(Poster abstracts in alphabetical order)

(# 1)
Monday, 5:40
Lobby

A Bayesian Analysis of Bias in Single Item Recognition for Continuous Word frequency. William R. Aue, *Syracuse University, United States of America*, Pernille Hemmer, *Rutgers University, United States of America*, Amy H. Criss, *Syracuse University, United States of America*. The relationship between word frequency (WF), measured on a continuous scale, and recognition memory was examined in a single item recognition task. The aim was to more clearly map the relationship between word frequency and memory performance. Contrary to standard findings of a linear relationship between WF and recognition, we observed a curvilinear pattern. Specifically, discriminability (d') is higher at both the low and very high ends of the WF continuum. In addition, we observe a liberal shift in bias (C) as WF increased. Variations of a Bayesian signal detection model were then applied to the data in order to better understand the influences WF on measures of d' and C. The models examined contrast current explanations of the WF effect in recognition where C does not influence performance with a model where C is free vary as a function of WF. Implications for models of recognition memory are discussed.

(# 2)
Monday, 5:40
Lobby

Fast and accurate calculations for Wiener diffusion models. Steven P. Blurton, *University of Regensburg, Germany*, Miriam Kesselmeier, *University of Heidelberg, Germany*, Matthias Gondan, *University of Heidelberg, Germany*. Diffusion models are widely used to model human behavior. Most models rely on the Wiener diffusion process with two absorbing barriers which allows not only predicting response times, but also two-choice decisions (Ratcliff, 1980, Psychol Rev). Despite this apparent appeal, Wiener diffusion models are numerically difficult to tract as the involved expressions are infinite series that exist in different representations. Thus, finding optimal parameters can take a lot of time and the quality of the obtained results is not always guaranteed. To avoid these problems, an improved method of calculating the first passage time density f(t) of a Wiener Process between two absorbing barriers was introduced by Navarro and Fuss (2009, J Math Psychol). This method not only controls the truncation error but is also computationally efficient because the representation is chosen that requires the least computational effort. Here, we provide a similar method to calculate the first passage time distribution F(t) and the

density of the underlying process g(x, t). In both cases, the number of terms needed for a pre-defined accuracy is calculated in advance which not only keeps the truncation error perfectly under control but also allows for choosing the representation which is least computationally demanding.

(# 3)
Monday, 5:40
Lobby

Confidence judgments in recognition memory. Beatrice Bora, *The University of Newcastle, Australia*, Richard D. Morey, *University of Groningen, Netherlands*, Andrew Heathcote, *The University of Newcastle, Australia*. We investigated recognition memory in a task requiring simultaneous confidence judgments and old (studied) vs. new (not studied) choices. Participants made a single response for one choice but classified confidence for the other choice over seven levels. Response time (RT) was measured, with response production time equated through moving a mouse to a semi-circular array of buttons. Participants were successfully encouraged to make full use of the available responses through increasing rewards for accurate and higher confidence responses. We examined the ability of the RTCON2 model to account for the effects of asymmetric numbers of confidence responses for each choice on accuracy and the distribution of RT.

(# 4)
Monday, 5:40
Lobby

Control of saccade timing during scene viewing by interaction of foveal and peripheral processing. Anke Cajar, *University of Potsdam, Germany*, Jochen Laubrock, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*. Visual processing is spatially inhomogeneous with the foveal visual field specialized in processing fine detail (high spatial frequencies) for object recognition and the peripheral visual field specialized in processing transients and coarse information (low spatial frequencies) for saccade target selection. This functional segregation has often been ignored when studying what guides the eyes through a complex natural scene. Here we investigated the effects of gaze-contingent spatial frequency filtering on eye movements. In several experiments, low or high spatial frequencies were attenuated in the foveal or peripheral visual field, thus simulating foveal scotoma or tunnel vision. Compared to a control condition, foveal filtering yielded longer and peripheral filtering shorter saccade amplitudes, indicating that subjects preferentially programmed saccades to unfiltered scene regions. Fixation durations increased when spatial frequency filters maintained more useful information (foveal high-pass, peripheral low-pass), but did not increase when useful information was strongly attenuated (foveal low-pass, peripheral high-pass). Thus, saccade programs were inhibited more strongly when visual processing was less impaired. We developed a computational model based on parallel random walks for saccade timing, foveal and peripheral processing, where a dynamic interaction of foveal and peripheral processing can inhibit the autonomous saccade timer. We will discuss our experimentally observed effects of fixation durations in the context of the mathematical model.

(# 5)
Monday, 5:40
Lobby

The impact of subjective recognition experiences on recognition heuristic use: A multinomial processing tree approach. Marta Castela, *University of Mannheim, Germany*, David Kellen, *University of Freiburg, Germany*, Edgar Erdfelder, *University of Mannheim, Germany*, Benjamin E. Hilbig, *University of Mannheim, Germany*. The recognition heuristic (RH) states that when deciding between two objects, with one being recognized by the decision-maker and the other not, choice will lie on the recognized one. It has consistently been shown that the recognized object is chosen more often in these cases, and different explanations for this result have been proposed. According to the original RH theory, the recognized object is chosen more often because the yes/no binary recognition judgment determines the inference and no other information will reverse that choice (the RH is being applied). Further studies have challenged this interpretation by demonstrating how further knowledge can be used and even overrule the recognition cue. This observation leads to a second explanation: the recognized object is chosen more often because further knowledge leads exactly to the same choice as recognition. Finally, a third explanation is based on the memory state heuristic framework that stresses the role of the memory states underlying the recognition judgment. According to this framework, the RH is applied more often when the recognized object is recognized with certainty. In this sense, not all recognition cases are treated alike. The three explanations make different predictions about the impact of subjective recognition experiences on use of the RH. Therefore, we will investigate use of the RH both for cases in which the recognized object was judged as merely recognized or as recognized with further knowledge. Our study consists of a reanalyses of 16 published data sets that include data about recognition experiences in the RH paradigm. To obtain an unbiased estimate of RH use for different recognition experiences we use the r*-model, a multinomial processing tree model that is an extension of the r-model by Hilbig, Erdfelder, and Pohl (JEP:LMC, 2010). The results point very clearly in the direction of the memory state heuristic. Implications for the role of memory processes in use of the RH are discussed.

(# 6)
Monday, 5:40
Lobby

Adaptive gain control during human perceptual choice. Samuel Cheadle, *Dept.Experimental Psychology, University of Oxford, Oxford, UK*, Valentin Wyart, *Dept. Études Cognitives, Ecole Normale Superieure, Paris, France*, Konstantinos Tsetsos, *Dept. Experimental Psychology, University of Oxford, Oxford, UK*, Nicholas Myers, *Dept. Experimental Psychology, University of Oxford, Oxford, UK*, Vincent de Gardelle, *CNRS UMR 8158, Laboratoire Psychologie de la Perception, 75006 Paris, France*, Christopher Summerfield, *Dept. Experimental Psychology, University of Oxford, Oxford, UK*. Optimal performance in psychophysical judgment tasks is captured by mathematical models in which decisions depend on linear integration of evidence. However, in the real world, decision-relevant evidence is often nonstationary, heterogenous

or otherwise incommensurable. Sensory systems have evolved to deal with variable input by adjusting the gain of processing to the match the statistics of the local environment, for example as the eye adjusts to ambient light levels over the diurnal cycle (adaptation). Analogously, we propose a model in which decision gain adapts towards the mean of the sampled distribution, allowing expected features to be processed with enhanced fidelity. We tested the model by asking human participants to categorise a 4Hz stream of eight visual gratings on the basis of their angle of orientation. The adaptive gain model correctly predicts the existence of three suboptimal biases in categorisation performance: (1) samples of evidence that bore similar information to their predecessor carried more weight in the eventual choice, independent of their perceptual similarity (commensurability bias); (2) samples of evidence that confirmed, rather than disconfirmed, the current belief of the observer were more influential (confirmation bias); (3) observers overweighted evidence that arrived closer in time to the decision (recent bias). These biases were not predicted by a corresponding model with no adaptive gain control. Moreover, we observed that this suboptimal variation in the weighting of decision information was mirrored by adjustments in pupil diameter, a general measure of cortical excitability during sequential information processing. These findings provide evidence for remarkably rapid and flexible gain control during decision-making, define limits on the optimality of human judgment, and place a strong new constraint on computational models of perceptual choice.

(# 7)
Monday, 5:40
Lobby

Using cognitive models to combine people's estimates of probabilities. Irina A. Danileiko Danileiko, *University of California, Irvine, United States of America*, Michael D. Lee, *University of California, Irvine, United States of America*. We demonstrate the usefulness of cognitive models in combining human estimates of probabilities in a real-world domain. Based on analysis of over 6000 first division football (soccer) games played in the past decade, we measured empirical ground truths to 40 questions about probabilities in these games, such as "what is the probability a team leading 1-0 at half time will win the game?" We collected estimates from 145 people on all 40 questions, and considered how their individual estimates could be combined to produce accurate group estimates. We show that insights from cognitive psychology, relating to individual differences in knowledge, and the mis-calibration of probabilities, allow for the development of models for aggregation that outperform simple statistical approaches.

(# 8)
Monday, 5:40
Lobby

Cognitive Aspects in Mathematics Assistant. Gabriella Daroczy, *MeiCogSci: University of Vienna, Austria*. The poster reports the outcomes of designing a dialogue system on the domain "simplification of fraction" in algebra: so that we try to match the benefits of theorem prover system (ISAC [2] designed for step-wise solving mathematics problems) with cognitive as-

pects. Designing the dialogue system based on cognitive aspects involves several design decision on: which information to collect about students action and how to react if students conduct an error, also taking into account that mathematics is grounded and embodied in everyday cognitive mechanism [3]. In the poster we also present a guided example on two levels of abstraction: on abstract symbolic level, and on an analogous "story" problem because: "Abstract representations may be more error prone than grounded", and many difficulties happen due the missing link between abstract and real life problems [1]. The goal is to give reflect on errors, provide information if requested, and encourage learners to solve problems (First field tests are planned in the close future). Answering what causes these errors is not the scope of the poster, rather showing the first implementation of error-patterns, fill-forms and experiences about guidelines from cognitive science in an educational context. References: [1] Koedinger, K. R., & Nathan, M. J. (2004). The real story behind story problems: Effects of representations on quantitative reasoning. *The Journal of the Learning Sciences, 13*(2), 129–164. [2] Neuper, W., Quaresma, P., & Back, R.-J. (Eds.) (2012) *Automated Generation of User Guidance by Combining Computation and Deduction Open Publishing Association, 79*, 82–101. [3] Nunez, R. (2004) Embodied cognition and the nature of mathematics: Language, gesture, and abstraction. In: *Proceeding of the 26th Annual Conference of the Cognitive Science Society, 36–37.*

(# 9)
Monday, 5:40
Lobby

Modelling eye movements in Multiple Object Tracking using neural networks. FILIP DECHTERENKO, *Academy of Sciences of the Czech Republic, Czech Republic; Faculty of Mathematics and Physics Charles University in Prague, Czech Republic*, JIRI LUKAVSKY, *Faculty of Mathematics and Physics Charles University in Prague, Czech Republic.* Multiple Object Tracking (MOT) is commonly used experimental paradigm to study distributed visual attention. In MOT people are asked to track several identical moving objects for several seconds. Although they can track the objects without eye movements only with their attention, if unconstrained they tend to move their eyes during the task. We focus on the question where people look and how gaze locations are influenced by positions of targets and distractors. So far, several high-level strategies were identified (centroid-looking, target-looking), but they explain only a small portion of the eye movement variability. It is an open question if we can improve the predictions using neural networks trained on the gaze data.In our research we measured eye movements in MOT task (4 targets, 4 distractors) from 58 participants; 95 trials per subject, each trial lasted 8 seconds. We trained several neural networks (10 instances for each condition) on this dataset while varying network structure and then compared similarity of predicted trajectories with actual eye trajectories using Normalized Scanpath Saliency metric. We discuss several preprocessing methods to increase the efficiency of neural networks training in MOT scenario. Results show that after permuting inputs

and smoothing the gaze data, the predictions of eye movements based on neural networks are comparable with centroid-looking model and in some trials they outperform this model.

(# 10)
Monday, 5:40
Lobby

The Dynamics of Intrusion in Cued Recall. Melody Dye, *Indiana University, United States of America*, Rui Cao, *Indiana University, United States of America*, Brendan Johns, *Indiana University, United States of America*, Simon Dennis, *The Ohio State University, United States of America*. In a pair of cued recall experiments, subjects studied lists of word pairs and were subsequently tested on their ability to produce the target word when cued at test. The first experiment followed the standard paradigm; in the second, subjects completed an encoding task in which they rated the association between items. Across both studies, frequency of the cue and target words were systematically varied. A regression over individual trials indicated that both accuracy and response time were well-predicted by cue frequency and cue+target bigram frequency, suggesting that the transitional probability between cue and target mediated ease of recall. A subsequent analysis of the errors seen at test, which comprised nearly 60% of attempted trials, revealed that different factors contributed to different intrusion types. Extra-list intrusions were both significantly higher frequency than intended targets, and significantly more likely given the cue word. By contrast, within list intrusions were both orthographically and semantically more similar to cues than the intended targets, particularly in Experiment 2, which saw a comparative increase in this intrusion type. We discuss the implications of these findings for models of cued recall.

(# 11)
Monday, 5:40
Lobby

Ranking Rankings: An Empirical Comparison of the Predictive Power of Sports Rankings. Garren R. J. Gaut, *UCI, United States of America; UCLA, United States of America*, Daniel Barrow, *Pitzer College, United States of America*, Peter Elliott, *UCLA, United States of America*, Ian Drayer, *UCLA, United States of America*, Braxton Osting, *UCLA, United States of America*. Rank-orderings naturally appear in a wide variety of domains. Consumers rank products, search engines recommend the most relevant documents and sports teams are ranked using a number of criteria. The broad nature of ranking problems has led to the development of many different ranking algorithms. In this paper, we consider several existing ranking methods and statistically compare their predictive power over various sports datasets under both a win-loss and score differential paradigm. An analysis of predictive power is presented using 20-fold cross validation and the Friedman and post-hoc Nemenyi tests. We find that the Rating Percentage Index (RPI) has the lowest predictive accuracy over all datasets. Conversely, the least squares (L2) and random walker (RW) methods have significantly higher predictive accuracy at the 95% confidence level than the other methods analyzed.

(# 12)
Monday, 5:40
Lobby

Mathematical modeling of social and psychological potentials of the management team in the conditions of innovative introductions. Vera G. Gryazeva-Dobshinskaya, *South Ural State Univercity, Russian Federation*, Julia A. Dmitrieva, *South Ural State Univercity, Russian Federation*. The current issue of the organized consultation practice is a selection of managers that are efficient in learning new professional purviews during the introduction of innovations. The research of the existing problem is based on complex program of psychological advanced audit of V.G.Gryazevoy-Dobshiskoy, who's one of the main subjects is identification of the command and role structure of enterprises management (technique of R.M.Belbins "Role in the teamwork"). 155 managers of enterprises took part in the research. The research revealed that identification of potential development of the managment team might be based on the methods of mathematical modeling correlation of activity tendency, aimed at modifications or preservation of the organization functioning parameters. Functioning model of the self-developing biologocal systems be V.Volterra was adapted to model the potential of development innovative activity of the management team. The optimum point model of the training impact (the balance point) in the process of further education of leadership competencies was built as a result of mathematical data modeling psychologocal diagnosis of team roles differentiation. On the basis of mathematical modeling of social and psychological potentials of a team one can build a differentiated educational programs of command and roleplaying leadership competencies for different groups of managers. This increases the efficiency of innovative management consulting organizations and optimization of cost organizations for staff training under the circumstances of innovative introductions.

(# 13)
Monday, 5:40
Lobby

Bayesian Adaptive Estimation of Psychometric Slope and Threshold with Differential Evolution. Hairong Gu, *Ohio State University, United States of America*, Jay I. Myung, *Ohio State University, United States of America*, Mark A. Pitt, *Ohio State University, United States of America*, Zhong-Lin Lu, *Ohio State University, United States of America*. The adaptive experimentation methodology has been adopted in visual psychophysical modeling in the pursuit of efficiency in experimental time and cost. The standard scheme only optimizes one design in each experimental stage, although simultaneous optimization of multiple designs per stage can be beneficial, but difficult to implement because of a surge in computation. In this study, we incorporated the adaptive experimentation methodology under a Bayesian framework with differential evolution (DE), an algorithm specialized in multi-dimensional optimization problems to explore the multiple-designs-per-stage approach. By taking advantage of parallel computing, DE is computationally fast. The results showed that the multiple-designs-per-stage scheme resulted in a more stable estimation in the early stages of the parameter estimation.

(# 14)
Monday, 5:40
Lobby

Threshold models of human decision-making on optimal stopping problems in different environments. Maime Guan, *University of California, Irvine, United States of America*, Andy Silva, *University of California, Los Angeles, United States of America*, Michael D. Lee, *University of California, Irvine, United States of America*. In optimal stopping problems, people must choose the maximum of a set of numbers presented in sequence. The challenge is that a number can only be chosen when it is presented, and it is not possible to go backwards in the sequence. We consider data involving 56 people making optimal stopping conditions in two different environments. In the plentiful environment, most of the numbers are relatively large, while in the scarce environment, most of the numbers are relatively small. We develop a simple threshold-based model of human decision-making on the task, and implement it as a Bayesian graphical model. Inferences for the key parameters of the model show that people are sensitive to the environmental distributions, especially through the setting of initial thresholds. We consider the relationship between human and optimal performance on the task, and a number of possible extensions to the model.

(# 15)
Monday, 5:40
Lobby

Model Selection by Minimum Description Length: Performance of the Fisher Information Approximation. Daniel W. Heck, *University of Mannheim, Germany*, Morten Moshagen, *University of Mannheim, Germany*. Multinomial processing tree (MPT) models are a family of stochastic models that can be used to explain categorical data by a sequence of latent processes. In experimental psychology, it is often desired to compare different MPT models in their ability to account for the data. For this purpose, information criteria that balance the fit of a model against its complexity are routinely applied. Recently, Wu, Myung, and Batchelder (2010) employed the principle of minimum description length to provide a new means of model selection, the Fisher information approximation (FIA). Unlike AIC and BIC, FIA has the theoretical advantage that it takes the functional form of the models into account, rather than measuring model complexity by the number of free parameters. The purpose of the present study was to compare the performance of AIC, BIC, and FIA in identifying the data generating model by means of a Monte Carlo simulation. Results indicate only minor differences among the criteria. Although FIA performed slightly better than AIC and BIC, the estimation of the complexity term used in FIA was found to be unstable, in turn questioning its use with small samples.

(# 16)
Monday, 5:40
Lobby

Adaptive gain during serial integration of visual information. Santiago Herce Castañón, *Department of Experimental Psychology, University of Oxford, United Kingdom*, Samuel Cheadle, *Department of Experimental Psychology, University of Oxford, United Kingdom*, Konstantinos Tsetsos, *Department of Experimental*

Psychology, University of Oxford, United Kingdom, Christopher Summerfield, *Dept. Experimental Psychology, University of Oxford, United Kingdom.* Optimal decisions involve integration of evidence to a threshold. An ideal observer categorising a stream composed of discrete samples of evidence of fixed reliability will afford equal weight to each. However, how an item is processed depends upon the context in which it is presented. For example, judgments about sensory stimuli are facilitated by an immediately preceding prime with which they share feature information. Here, we tested the hypothesis that during serial integration, an observers' sensitivity to evidence varies according to the statistics of the preceding information. Sixteen human observers categorised a stream of 10 visual gratings according to their average angle of orientation. On one third of trials, the sequence was interrupted after a random number of samples, and observers were asked to estimate the tilt of the immediately preceding grating by turning a continuous dial. We observed that estimation judgments were more accurate when the to-be-judged sample was more similar to its predecessors. On remaining trials, the impact which each sample had on decisions increased when it was more similar to the mean information viewed. These findings can be explained by a simple model in which the gain of information processing adapts to meet the statistics of recent evidence.

(# 17)
Monday, 5:40
Lobby

Learning rules in judgment: A comparison of the delta-learning rule and linear regression models.

Janina Anna Hoffmann, *University of Basel, Switzerland*, Bettina von Helversen, *University of Basel, Switzerland*, Jörg Rieskamp, *University of Basel, Switzerland.* Making accurate judgments such as choosing a suitable job candidate presumes an adequate weighting of more and less important aspects, say the candidate's skills. In social judgment theory, these weighting processes have often been modeled by linear regression models. Indeed, linear regression models successfully describe well-learned judgments in multiple-cue judgment tasks. How people learn to make judgments has received less attention. By employing the delta-learning rule, connectionist models can perfectly learn to solve linear problems and it has been proposed that these models may also describe human learning processes. In a reanalysis of two experiments, we compared how well a linear regression model and two versions of the delta-learning rule can describe and predict people's judgments in two linear judgment tasks: a perfectly predictable task and a noisy one. In both experiments, participants first learned to predict the judgment criterion in a training phase. In the subsequent test phase, participants made judgments for new items without getting any feedback. In the perfectly predictable task, the linear regression model described participants' judgments better than the delta learning rule at the end of the training phase (compared by BIC). In addition, the linear regression model predicted participants' judgments more accurately in the test phase (based on RMSD). In the noisy judgment task, however, the delta-learning rule described participants' judgments at the end of the training phase as well as the linear regression model. Also, the linear model

did not make more accurate predictions for items in the test phase. Further analyses showed that the delta-learning rule systematically overestimates how accurately people abstract less important cues in the perfectly predictable task. In the noisy task, however, all cues were given similar weights. Taken together, these results suggest that successful learning models need to account for differences in learning speed between cues.

(# 18)
Monday, 5:40
Lobby

The influence of upcoming words in reading: Simulations with the SWIFT model of eye-movement control. Sven Hohenstein, *University of Potsdam, Germany*, Sarah Risse, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*. Eye movements in reading are influenced by features of words in foveal and parafoveal vision. There is an ongoing debate on how upcoming words affect gaze control. We present results from a simulation study using the SWIFT model of eye-movement control in reading. In this model, the processing span is dynamically modulated by the processing state of the fixated word. In an extension, both foveal and parafoveal words can contribute to the modulation of size of the processing span. Implications of gaze-contingent display change experiments on distributed processing can be captured within the SWIFT framework. We applied the new implementations to experimental data and demonstrate that SWIFT is a viable model for eye-movement control during reading of words in foveal and parafoveal vision.

(# 19)
Monday, 5:40
Lobby

Recalling Spoons and Knives: A Multinomial Modeling Analysis of the Development of Clustering in School-Age Children. Sebastian Horn, *Max Planck Institute for Human Development (Center for Adaptive Rationality), Berlin*, Ute J. Bayen, *Heinrich-Heine-Universität Düsseldorf*. Younger children's memory output is typically less organized semantically than that of older children or adults. In this developmental study, we examined changes in clustering in free recall across trials. Younger adults (M = 22 years of age), fourth graders (M = 10 years) and first graders (M = 7 years) heard categorically related words in a repeated study-test paradigm. To measure the contributions of storage and retrieval underlying clustering, we used a reparametrized version of W.H. Batchelder's and D.M. Riefer's (1986) multinomial processing tree model, thus taking the learning rate across trials into account. The modeling revealed (a) age differences in cluster storage, and (b) an increase in cluster storage across study-test trials. This increase was substantially larger for adults than for children. The results suggest that younger children's (particularly first grader's) clustering hardly changes with repeated list presentations, although their recall performance increases.

(# 20)
Monday, 5:40
Lobby

Modeling speed-accuracy trade-off curves. Asli Kiliç, *Koc University, Turkey*, Ilke Oeztekin, *Koc Univer-*

sity, Turkey. The speed-accuracy trade-off (SAT), caused by individuals' tendency to trade response time for accuracy and vice versa, is a common problem in psychological research. One way to account for this tendency is to employ a response deadline procedure. By providing a full time-course function describing how cognitive processing unfolds over time, the response deadline procedure can allow unbiased estimates of accuracy and speed independently. In this investigation, we evaluated and compared two approaches to model SAT curves derived from the response deadline procedure, namely least squares estimation (LSE, McElree & Dosher, 1989) and maximum likelihood estimation (MLE, Liu & Smith, 2009). To do so, we reanalyzed two published recognition memory studies (Öztekin & McElree, 2007; Öztekin & McElree, 2010), as well as two new empirical data sets that employ the response deadline procedure. For each of the four data sets, individual participants' data was fit with both the LSE and MLE methods. Results indicated comparable parameter estimates and model fit statistics across the two approaches. In addition, statistical comparisons on the parameter estimates across participants in each data set also indicated the same best-fitting model for both LSE and MLE methods. Accordingly, we suggest that both LSE and MLE methods can provide effective approaches for modeling SAT curves.

(# 21)
Monday, 5:40
Lobby

Saccadic localization of word centers during reading: A Bayesian model. André Krügel, *University of Potsdam, Germany*, Ralf Engbert, *University of Potsdam, Germany*. During reading, saccadic eye movements shift new words into the fovea for lexical processing. Most reading theories assume that readers aim at word centers, but readers' eye movements systematically over- or undershoot the word center if saccades are launched from short or long distances to the target position. The dominating interpretation of this robust finding in the literature is that of a fundamental range error in the oculomotor system. Here we present a Bayesian model for saccade planning during reading which is based on the idea that noisy sensory information about the position of a target word is combined with extra-sensory prior knowledge about target-word distances in reading. Using a large corpus of eye-movement recordings we show that the systematic launch-site contingent error of saccade landing positions within words during reading is consistent with the assumption that readers use Bayesian estimation to compute optimal estimates of the position of the next word center for saccade planning.

(# 22)
Monday, 5:40
Lobby

What can racing diffusion processes inform us about visual search? Fabio Leite, *Ohio State University, Germany*. In perceptual decisions based on simple stimuli, what happens with the decision processes and with non-decision perceptual and motor processes as the number of alternatives increases? Following Leite and Ratcliff (2010), response time and accuracy data were collected from a multiple-location search paradigm in which stimulus difficulty and probability of the response alternatives were varied (across nine and eleven participants, respectively)

along with number of response alternatives (viz., two, four, and eight locations). I will discuss the results from fitting sequential sampling models using racing diffusion processes to the data. Key observations were that the degree of caution increased as the number of alternatives increased (consistent with previous findings), non-decision encoding time did not increase monotonically with number of alternatives (as it could be inferred based on previous paradigms), that a parameter in the model could capture the effects of attentional neglect on unavailable alternatives (in the cases of two and four alternatives), and that input strength parameters captured the effects of both difficulty and probability manipulations, suggesting these parameters can accommodate attentional adjustments as well as evidence quality.

(# 23)
Monday, 5:40
Lobby

Modeling Overdistribution in Source Memory: Memory versus Guessing-Based Accounts. Julie Linzer, *Albert-Ludwigs-Universität Freiburg, Germany*, David Kellen, *Albert-Ludwigs-Universität Freiburg, Germany*, Henrik Singmann, *Albert-Ludwigs-Universität Freiburg, Germany*, Karl Christoph Klauer, *Albert-Ludwigs-Universität Freiburg, Germany*. An important distinction in the memory literature is between item memory and source memory. While item memory concerns the ability to remember previously acquired information ("Did I see this word before?"), source memory is concerned with contextual details associated with the acquisition of information (e.g., "Was this word in List A or B?"). One prominent model measurement that captures the different cognitive processes underlying item and source-memory judgments is the two-high threshold source-memory model (2HTSM; Bayen, Murnane, & Erdfelder, 1996). A recently-reported phenomenon entitled source overdistribution (Brainerd, Reyna, Holliday, & Nakamura, 2012) suggests that individuals can attribute an item to different sources simultaneously (List A and List B) even when this is known to be impossible. It has been argued that the response pattern constituting this phenomenon is inconsistent with the 2HTSM and a new model that departs from traditional theoretical frameworks has been proposed. A reevaluation of source overdistribution shows that the latter can be recast by the 2HTSM as a simple guessing-based phenomenon. Furthermore, a comparison of hierarchical-Bayesian implementations of the candidate models based on new experimental data shows that the 2HTSM is not only able to account for source overdistribution, but also provides the best overall account of the data.

(# 24)
Monday, 5:40
Lobby

Individual differences in use of the recognition heuristic. Martha Michalkiewicz, *University of Mannheim, Germany*, Alisha Coolin, *Simon Fraser University, Canada*, Edgar Erdfelder, *University of Mannheim, Germany*. According to the recognition heuristic (RH), when faced with a recognized object and an unrecognized one, people make inferences based on recognition alone. One of the most studied examples is the city-size task. In this task, participants are asked which of two cities is more

populous. While prior work has identified noteworthy individual differences in use of the RH, there is limited research exploring these differences. Furthermore, there is a large body of research showing that decision making, and use of heuristics in particular, are affected by personality characteristics. Thus, we extended the r-model, a multinomial processing tree model assessing RH use, to identify whether personality factors account for individual variation in use of the RH. In a series of experiments, participants completed several personality questionnaires and the city-size task to assess RH use. We directly incorporated individuals' personality measure scores into the estimation of model parameters using a logistic link function. Based on previous findings, we expected a positive relation between RH use and impulsivity, promotion, extraversion, and neuroticism. On the other hand, we expected a negative relation between RH use and anxiety and between RH use and prevention. This research will identify the influence of personality factors on use of the RH.

(# 25)
Monday, 5:40
Lobby

Slamming the "Hot-Hand Fallacy". Brent Miller, *University of California, Irvine*, Michael D. Lee, *University of California, Irvine*. We introduce evidence that supports the notion of a "hot hand" in basketball scoring, based on detailed play-by-play information for NBA players over the 2012-2013 season, including player's shot time and basketball court location. We analyze this information using a psychometric item response model where shots are matched by difficulty, and player responses are conditioned on what their previous shooting record is. When features such as player skill and shot difficulty are taken into account, the likelihood of a scoring run being followed by another success increases significantly compared to baseline performance. We also find that while players can be more successful when they are doing well, this is tempered by their tendency to take more challenging shots in these situations.

(# 26)
Monday, 5:40
Lobby

A classification-image-like method reveals observers' strategies in two-alternative forced choice tasks. Richard F. Murray, *York University, Canada*, Lisa M. Pritchett, *York University, Canada*. There is still disagreement about how observers perform even the simplest tasks, such as making 2AFC decisions, despite decades of research. One difficulty in testing models of decision making is that we must usually compare human performance across different tasks, such as 2AFC and yes-no tasks. However, different tasks put different demands on memory, attention, and other poorly understood behavioural limits, and this makes it difficult to find persuasive tests of models based on performance differences across tasks. It would be much easier to test models of decision making if we had access to observers' decision variables on individual trials in a single task. Here we demonstrate a novel method of using classification images to calculate "proxy decision variables" that estimate an observer's decision variables on individual trials. We tested the hypotheses that observers base their decisions in 2AFC tasks on (a) the difference between the decision variables for the two intervals, (b) independent yes-no decisions in the two

intervals, or (c) just one of the intervals. Method. Twelve observers viewed two disks in Gaussian noise, to the left and right of fixation, and judged which had a contrast increment. For each trial we calculated the cross-correlation of the classification image with the two disks, providing a proxy decision variable for each alternative. After several thousand trials we mapped the observer's decision space: we plotted the probability of choosing the right-hand disk as a function of the two proxy decision variables. The resulting decision space map is the true decision space map convolved with a Gaussian kernel that is determined by the error in the classification image and the magnitude of the observer's internal noise. Results. Decision space maps showed that the boundary between the two response regions (i.e., response "left of fixation" or "right of fixation") was a line along the main diagonal, indicating that observers based their decisions on the difference between the decision variables from the two intervals. The independent yes-no decision model (hypothesis (b) above) predicts a checkerboard pattern in the decision space. The single-interval model (hypothesis (c) above) predicts a horizontal or vertical decision line. Neither of the latter two patterns was found for any observer. We conclude that the difference model favoured by signal detection theory is a valid model of 2AFC decisions.

(# 27)
Monday, 5:40
Lobby

Active Inference in Decision Fields. Dirk Ostwald, *Center for Adaptive Rationality (ARC), Max Planck Institute for Human Development, Berlin*, Felix Blankenburg, *Center for Adaptive Rationality (ARC), Max Planck Institute for Human Development, Berlin ; Dahlem Institute for Neuroimaging of Emotion (DINE), Freie Universität Berlin*, Ralph Hertwig, *Center for Adaptive Rationality (ARC), Max Planck Institute for Human Development, Berlin.* Understanding the neural constraints of risky decision making from description holds great potential for improvements in human risk communication. Recently, stochastic time-series models (STSMs) have proven as a useful basis for integrating the cognitive and neurobiological study of perceptual decision making. Because STSMs address both psychological intuitions on cognitive process unfolding and fundamental aspects of EEG data, it is believed that STSMs also form a useful starting point for the noninvasive study of the neural basis of risky decision making. A well-developed STSM for preferential choice is Decision Field Theory (Busemeyer and Townsend, 1993). In brief, Decision Field Theory (DFT) corresponds to a continuous-time, continuous-state non-homogenous Ornstein-Uhlenbeck process (OUP), whose governing parameters convey psychological intuitions, such as attention switching, memory decay, and approach-avoidance conflicts. However, the direct empirical validation and predictive power of DFT for neuroimaging has not been explored so far. The aim of this theoretical study is to make DFT directly accessible to Bayesian model identification and to derive neurobiologically plausible DFT predictions for EEG experiments. The study comprises three parts. First, we establish a mapping between cognitive process constructs and mathematical descriptions of DFT for binary gamble tasks. We demonstrate how three different decision strategies (the Minimax heuristic, the lexicographic

heuristic, and the evaluation of expected values (Brandstätter et al., 2006)) can be accommodated under the DFT framework and result in quantitatively different diffusion behavior. Second, we demonstrate the Bayesian identification of latent DFT models using Variational Bayes (VB) for STSMs (Ostwald et al., under review). VB corresponds to an analytical approximate-inference scheme and offers reduced computational costs as compared to sampling-based MCMC techniques. Finally, we reconsider DFT under the premise of Active Inference (Friston et al., 2012). Active Inference is a neurobiologically plausible VB variant that allows us to directly derive differential predictions for DFT-embedded decision strategies in terms of nested EEG oscillations. In sum, our analysis lays the necessary theoretical groundwork for the evaluation of DFT in the neurobiological context and as such forms a necessary prerequisite for the study of the neural constraints of human risky decision making.

(# 28)
Monday, 5:40
Lobby

Evaluating the estimation accuracy of Ordinary Least Squares. Sang Hyuk Park, *University of Missouri - Columbia, United States of America*, Clintin P. Davis-Stober, *University of Missouri - Columbia, United States of America*. Davis-Stober and Dana (2013) presented a new measure of estimation accuracy, the v measure, which compares the mean squared error of the ubiquitous Ordinary Least Squares (OLS) estimator to a naïve, benchmark estimator that randomly determines the direction and magnitude of treatment effects. The v measure was originally described as a method to be used in conjunction with standard power analyses to determine sample size prior to data collection. We investigate the distributional properties of v when applied to collected data as a statistic. We demonstrate via a series of simulation studies that v provides meaningful information about estimation accuracy above and beyond that provided by p-values or confidence intervals.

(# 29)
Monday, 5:40
Lobby

Generatively Connecting Multidimensional Scaling Representations to Data. James Pooley, *University of California, Irvine, United States of America*. In the cognitive sciences, multidimensional scaling (MDS) is often used to construct a "psychological space" that serves as the common representational basis for models of various cognitive processes. This constructions is typically a two-step process: In the first step, an MDS algorithm is used to construct a representational space based on data from one experimental task (e.g., stimulus identification); in the second, a cognitive process model operates on this representation to predict data collected on a second experimental task based on the same set of stimuli (e.g., stimulus categorization). Highlighting and extending unappreciated, 30-year-old work in the psychometric literature, we demonstrate how MDS models can be embedded into a generative, hierarchical Bayesian framework in which the common representational space underlying various tasks is constructed in a single step based on the simultaneous use of the data from these tasks.

(# 30)
Monday, 5:40
Lobby

Simulating the processing span reading with the SWIFT model. Sarah Risse, *Universität Potsdam, Germany*, Sven Hohenstein, *Universität Potsdam, Germany*, Ralf Engbert, *Universität Potsdam, Germany*. How processing of foveal and parafoveal words is coordinated in order to guide the eyes during reading is still an open question and only partly understood. Computational modeling can help to unravel the underlying processes evaluating the model outcome against the empirical data. Moreover, such models allow the investigation of internal process behavior that goes way beyond what is possible in experimental research. We used a stochastic model based on a word-level activation field reflecting parallel word processing during reading [SWIFT3: Schad & Engbert, 2012, Visual Cognition, 20, 391-421]. We tested three different implementations of the processing span determining the words that can be processed during a reading fixation: one constant and two dynamical spans modulated by foveal and parafoveal processing difficulty. The variants were compared and evaluated on their performance in a gaze-contingent reading task manipulating parafoveal processing of word N+2. Simulations revealed that the SWIFT variants all could reproduce various parafoveal preview effects and that their differences on parafoveal processing were rather subtle. Moreover, analyses of the model dynamics for variations in the parameters identified assumptions that seem related to the integration of foveal and parafoveal processing and interesting for future experimental research.

(# 31)
Monday, 5:40
Lobby

Estimating Averages of Skewed Tone Durations. Richard Schweickert, *Purdue University, United States of America*, Hye Joo Han, *Purdue University, United States of America*, Motonori Yamaguchi, *Vanderbilt University, United States of America*, Claudette Fortin, *Universite Laval, Quebec, Canada*. Subjects were presented with a series of tones and estimated their average duration. Durations of tones in a series were sampled from one of three distributions, with different means and skewnesses. According to Scalar Timing Theory (Gibbon, 1981), the representation of a tone in long term memory follows the formula T = A +BD, where T is the duration in memory of a tone with presented duration D, A and B are random variables, and B is typically less than 1. The formula predicts estimates of average would be a linear function of presented averages, with slope less than 1, and variances of estimates of averages would be a linear function of presented averages squared. In Experiments 1 and 2 estimates of average were influenced by extraneous tone durations, those from previous blocks with different distributions and those of tones presented for comparison. Extraneous tone durations were removed in Experiment 3. Each subject was presented with tones sampled from only one distribution. Also, durations of tones presented for comparison were percentiles of the distribution sampled from. In Experiment 3 the two predictions of Scalar Timing Theory were satisfied. Skew had little role in estimation of average duration.

(# 32)
Monday, 5:40
Lobby

Link Prediction in Social Network Analysis of Dream Reports: Common Neighbors and Future Dream Cooccurrence. Hye Joo Han, *Purdue University, United States of America* Richard Schweickert, *Purdue University, United States of America* . In a social network, a person connected to two other people by edges is called a common neighbor of the two. Lubbers et al. (2010) found that having several common neighbors for two people can increase persistence and formation of edges between them using longitudinal analysis of personal networks. The present study uses a long dream series to construct a series of social networks in different time intervals. Each dream social network is constructed by joining two people with an edge if they appear in dreams together. Longitudinal analysis of the dream social networks found that the number of common neighbors for people who remain connected is much greater than that for people who become disconnected. In further analysis, several link prediction methods based on common neighbors were used. Each prediction method scores proximity between people. Actually formed edges were compared with edges predicted by the highest proximity scores. Results suggest information about common neighbors can make link predictions that are much more accurate than random predictions. Moreover, more complex methods that control the contributions of common neighbors with different degrees outperform the simplest method that only counts the number of common neighbors.

(# 33)
Monday, 5:40
Lobby

An integrated model of voluntary saccades and microsaccades. Petra Sinn, *University of Potsdam, Germany*. We extended an integrated model of fixational eye movements and microsaccades (Engbert, Mergenthaler, Sinn, & Pikovsky, 2011, PNAS) to reproduce the statistics of slow drift movements, microsaccades, and saccades. We asked human observers to perform a scanning task with small items presented on a linear chain with distances less than 1 degree of visual angle. As a result, we observed small scanning saccades along the chain as well as microsaccades not related to sequential gaze shifts along the chain of items. Interestingly, the saccades and microsaccades could be distinguished by their correlation to slow drift movements before the saccadic events. The model was able to predict the correct statistical dependency between saccadic events and drift movements. Our model simulations are compatible with the view that small scanning saccades and microsaccades are generated by the same mechanism

(# 34)
Monday, 5:40
Lobby

Comparing parameter estimation techniques. Tyler Thrash, *Miami University, United States of America*, Robin Thomas, *Miami University, United States of America*. One way of determining the best-fit values of a model's parameters is to test every possible combination of values within certain constraints. However, this approach is rarely feasible for models with a large number of parameters. For these

higher-dimensional models, "parameter estimation techniques" are often used in order to increase the computational efficiency with which an "adequate" solution can be found. There are several different types of parameter estimation techniques used in various scientific literatures but few empirically grounded guidelines for determining which technique is best for a particular problem. Often, a particular parameter estimation technique is used because of convention within a particular field or computational efficiency. For the present study, we compare two parameter estimation techniques (i.e., hill-climbing and genetic algorithms) and their abilities to approximate the guaranteed optimal solution, in terms of bias, relative efficiency, and consistency, using models of perceptual classification.

(# 35)
Monday, 5:40
Lobby

Using spatial point processes to evaluate models of eye guidance in scene viewing. Hans A. Trukenbrod, *University of Potsdam, Germany*, Simon Barthelmé, *University of Geneva, Switzerland*, Felix A. Wichmann, *University of Tübingen, Germany*, Ralf Engbert, *University of Potsdam, Germany*. The distribution of fixation locations on a stationary visual scene can be interpreted as an intensity function of an underlying spatial point process (Illian et al., 2008). In point process theory, we try to analyze the point-to-point interactions to infer possible generating mechanisms. The pair correlation function provides a mathematical measure of the density and statistical interaction of neighboring points. We explore the possibility to apply the pair correlation function in the spatial statistics of fixation locations generated from individual scanpaths of human observers. We demonstrate that the inhomogeneous pair correlation function removes first-order heterogeneity induced by systematic variation of saliency within a given scene from second-order spatial statistics. Results indicate significant spatial clustering at short length scales. Finally, we use the inhomogeneous pair correlation function for the evaluation of a dynamical model of saccade generation in active vision during scene perception.

(# 36)
Monday, 5:40
Lobby

How to Deal with Violations of Regular Minimality in an Application of Fechnerian Scaling to Data on Lightness Perception? Nora Umbach, *University of Tübingen, Germany*. Fechnerian Scaling allows us to reconstruct subjective distances among stimuli from their discriminability. The only empirical requirement that data has to fulfill in order to apply Fechnerian Scaling is Regular Minimality. A matrix of discrimination probabilities satisfies Regular Minimality if a probability minimal in its row is minimal in its column. Fechnerian Scaling has to be applied to a matrix of "true" discrimination probabilities. When collecting psychophysical data we do not get "true" probabilities, though. Trendtel et al. (2010) and Dzhafarov et al. (2011) derive a formula for testing if a certain number of violations of Regular Minimality for a given matrix are statistically significant, but one still has to decide how to deal with these violations. Throwing out stimuli which violate Regular Minimality, even though these violations are small and do not look systematic, seems

like a terrible waste of data. Dzhafarov and Colonius (2006) introduce a family of models that can predict data that are compliant with Regular Minimality, the Quadrilateral Dissimilarity Model. We tried to fit this model to data obtained in an experiment investigating the perceptual space of achromatic surface colors. Subjects had to judge if two gray patches presented for 500 ms looked same or different. The Quadrilateral Dissimilarity Model predicted data which were Regular Minimality compliant, so that Fechnerian Scaling could be applied to the full data set. Problems and implications of this method are discussed.

(# 37)
Monday, 5:40
Lobby

Decision rules in expanded judgement. Leendert Van Maanen, *University of Amsterdam, The Netherlands*, Scott Brown, *University of Newcastle, Australia*, Birte U. Forstmann, *University of Amsterdam, The Netherlands*, Eric-Jan Wagenmakers, *University of Amsterdam, The Netherlands*. Optimal models of decision making assume that people accumulate evidence for a particular response alternative up to a fixed, preset response criterion. As soon as one of the alternatives hits the criterion a decision is made. One popular assumption is that decision makers set this criterion in such a way that on average they reach a satisfactory level of accuracy; that is, they optimize response speed for a satisfactory probability of being correct (the Sequential Probability Ratio Test SPRT).An implicit assumption of the SPRT is that during a trial, the response criterion does not change. However, recent studies suggest that the response criterion may be change over time (eg, as an "urgency" signal). In an expanded judgement task, the assumption of a fixed response criterion was tested. Because in this task the actual amount of evidence for each response alternative is known, the evidence for each alternative at the moment of the response can be computed. This provides a measure of the response criterion actually applied by participants on a trial-by-trial basis. We hypothesized that as the response time increases, the response criterion actually decreases, reflecting the increased sense of urgency that participants may have.

(# 38)
Monday, 5:40
Lobby

Modeling exploration-exploitation behavior across tasks reveals little evidence for a common factor. Bettina von Helversen, *University of Basel, Switzerland*, Rui Mata, *Max Planck Institute for Human Development*, Greg Samanez-Larkin, *Vanderbilt University*, Andreas Wilke, *Clarkson University*. The need for exploration is ubiquitous. For most of us, not a day goes by in which we do not search for parking spots, online news, or names from memory. However, exploration can be costly. For instance, exploring unknown options reduces the possibility to exploit known ones. In the present work, we investigated whether people show a general tendency to explore or exploit that can be captured across situations. For this, we examined and modeled individuals exploration-exploitation behavior in three computerized tasks: a foraging task involving sequential search for fish in several ponds, a sequential choice task involving choosing a candidate from a pool of applicants, and a multi-armed bandit task. Structural equation modeling

on the behavioral measures revealed that there was no general factor underlying exploration in all tasks, even though exploration was highly consistent within each task. Furthermore, model parameters measuring exploration/exploitation were not correlated between tasks. The results suggest that exploration behavior is largely dependent on the task context and there is little evidence for a general tendency to explore or exploit.

(# 39)
Monday, 5:40
Lobby

Modeling Response Bias: A Static or Dynamic Signal? Chelsea Erin Voskuilen, *The Ohio State University, United States of America*, Roger Ratcliff, *The Ohio State University, United States of America*. We used a diffusion model to examine the effects of a bias manipulation on response time data collected from a two-choice asterisk task. In this task, subjects are asked to determine whether the number of asterisks in a 10x10 grid was a large or small number, based on an experimenter-provided cutoff value. On some blocks of trials, there were an equal number of large and small trials. On other blocks of trials, there were either three times more large trials or three times more small trials. At the beginning of each block of trials, subjects were informed about the relative frequencies of large and small trials. Consistent with previous research (Leite & Ratcliff, 2011; Ratcliff, Van Zandt & McKoon, 1999), the bias manipulation was best accounted for by changes in the starting-point of the diffusion process. Unlike recent work by Hanks, Mazurek, Kiani, Hopp, and Shadlen (2011), we found no evidence for changes in the drift criterion as a function of the bias manipulation or as a function of elapsed decision time.

(# 40)
Monday, 5:40
Lobby

Custom distributions and functions in JAGS. Dominik David Wabersich, *University of California, Irvine, United States of America; University of Tübingen, Germany*, Joachim Vandekerckhove, *University of California, Irvine, United States of America*. JAGS is a cross-platform and open-source piece of software that provides general purpose methods, in particular MCMC methods, which can be used to easily evaluate Bayesian graphical models and estimate model parameters. Though many standard distributions and functions already exist, JAGS can be extended to incorporate more complex and nonstandard models, by writing custom modules.We have successfully implemented complex custom distributions and functions for use in JAGS. Here we provide examples of custom JAGS implementations of well-known cognitive models. The JAGS framework allows us to extend these cognitive models in order to allow for individual differences in addition to experimental manipulations.Additionally, we provide details on the practical implementation of custom JAGS modules.

(# 41)
Monday, 5:40
Lobby

Computational Modeling of Decision Making in Alcohol Dependence. Sinem Balta Beylergil, *Neural Information Processing Group, Technische Universität Berlin, Germany, Berstein Center for Computational Neuroscience, Berlin,*

Germany, Anne Beck, *Department of Psychiatry and Psychotherapy, Charité Universitätsmedizin, Berlin, Germany*, Lorenz Deserno, *Department of Psychiatry and Psychotherapy, Charité Universitätsmedizin, Berlin, Germany*. Andreas Heinz, *Department of Psychiatry and Psychotherapy, Charité Universitätsmedizin, Berlin, Germany, Berstein Center for Computational Neuroscience, Berlin, Germany*. Klaus Obermayer, *Neural Information Processing Group, Technische Universität Berlin, Germany, Berstein Center for Computational Neuroscience, Berlin, Germany*. Inhibitory control is an essential component of optimal decision making, dysregulation of which might explain some prominent features of addiction such as compulsive substance use and loss of self-control. Reversal learning paradigm, in which subjects must learn to respond to formerly irrelevant stimulus-reward pairing, has been used in many animal and human learning studies. However, the focus has been more on error pattern analyses and the underlying computational principles have not been analyzed in depth as far as alcohol addiction is concerned. In this study, we used computational modeling to shed light on the impaired mechanisms of decision making in alcohol addiction. The study sought answer to four questions (a) Does the alcohol-dependent group (AG) have impaired reversal learning? (b) Does the AG group show greater perseveration than the control group (CG)? (c) Do the subjects assign symmetrical values to positive and negative feedback? (d) What might account for the group differences in reversal learning- if any? We used the probabilistic reversal learning task, since it has been demonstrated that it is a valid task for the evaluation of the response shifting difficulty after a change in contingencies, which is often related to compulsive and habitual response tendencies in addiction. We had 35 abstinent alcohol-dependent and 26 control subjects (age, sex and IQ matched). We considered three computational learning models: (1) a simple Q-learning model which updates solely the value of the chosen stimulus with a prediction error after each trial, (2) a variant of the Q-learning model which updates both the values of the chosen and unchosen stimuli simultaneously and (3) a Hidden Markov model based on Bayesian belief propagation. Additionally, to test our question (c), each model had two variants: one assigns symmetrical and the other assigns asymmetrical free parameters to the magnitudes of positive and negative feedback. The results showed that AG scored worse and needed more trials to reach the reversal criteria which depend on performances of subjects. At the time of reversals AG shifted their response later than CG, showing greater perseveration. The equally best fitting models (2) and (3) both illustrated that subjects generally assigned lower values to the negative feedback than the positive feedback. Furthermore, model parameters showed that AG subjects had lower degree of aversion from negative feedback and attenuated expectation of punishment as a consequence of a mistake. Our results suggest that "punishment" as a result of an incorrect response might not create enough salience to evoke attention and/or working memory in alcohol addiction causing perseveration in behavior.

(# 42)
Monday, 5:40
Lobby

Univariate Normalization of Bispectrum Using Hoelder's Inequality. FOROOZ SHAHBAZI AVARVAND, *Fraunhofer FOKUS, Department of Automotive services and communication technologies, Berlin, Germany, Humboldt-Universität zu Berlin, Faculty of Mathematics and Natural Sciences, Berlin, Germany*, ARNE EWALD, *Deptartment of Neurophysiology and Pathophysiology, Hamburg, Germany*, GUIDO NOLTE, *Deptartment of Neurophysiology and Pathophysiology, Hamburg, Germany*. Considering that many biological systems including the brain are complex non-linear systems, suitable methods capable of detecting these non-linearities are required to study the dynamical properties of these systems. One of these tools is the third order cummulant or cross-bispectrum, which is a measure of interfrequency interactions between three signals. For convenient interpretation, interaction measures are most commonly normalized to be independent of constant scales of the signals such that its absolute values are bounded by one, with this limit reflecting perfect coupling. Although many different normalization factors for cross-bispectra were suggested in the literature these either do not lead to bounded measures or are themselves dependent on the coupling and not only on the scale of the signals. We suggest a normalization factor which is univariate i.e, dependent only on the amplitude of each signal and not on the interactions between signals. Using a generalization of Hoelder's inequality it is proven that the absolute value of this univariate bicoherence is bounded by zero and one. We compared three widely used normalizations to the univariate normalization concerning the significance of bicoherence values gained from resampling tests. Bicoherence values are calculated from real EEG data recorded in an eyes closed experiment from 10 subjects. The results show slightly more significant values for the univariate normalization but in general, the differences are very small or even vanishing in some subjects. Therefore, we conclude that the normalization factor does not play an important role in the bicoherence values with regard to statistical power, although a univariate normalization is the only normalization factor which fulfills all the required conditions of a proper normalization.

Author Index

Brown, Scott
Scott.Brown@newcastle.edu.au, 18, 20, 32, 97
Burdakov, Oleg
oleg.burdakov@liu.se, 34
Busemeyer, Jerome R.
jbusemey@indiana.edu, 12, 70, 77

Cadez, Eva
ecadez@ucmerced.edu, 69
Cajar, Anke
cajar@uni-potsdam.de, 80
Cao, Rui
caorui@umail.iu.edu, 84
Castela, Marta
martavcastela@gmail.com, 81
Cavagnaro, Daniel R.
cavdaddy@gmail.com, 43
Chang, Ting-Yun
heart1991616@gmail.com, 36
Cheadle, Samuel
sam.cheadle@psy.ox.ac.uk, 81, 86
Chechile, Richard A.
Richard.Chechile@tufts.edu, 28
Childers, Russ
russ@eccles.psy.ohio-state.edu, 19
Cohen, Jonathan D.
jdc@princeton.edu, 20
Colonius, Hans
hans.colonius@uni-oldenburg.de, 12
Cook, John
j.cook3@uq.edu.au, 28
Coolin, Alisha
acc27@sfu.ca, 90
Cox, Gregory E.
grcox@indiana.edu, 59, 60
Criss, Amy H.
acriss@syr.edu, 59, 65, 79
Crupi, Vincenzo
vincenzo.crupi@unito.it, 23

Dai, Junyi
junydai@indiana.edu, 77
Dal Forno, Arianna
arianna.dalforno@unito.it, 69
Danileiko, Irina A. Danileiko
idanilei@uci.edu, 82
Daroczy, Gabriella
gdaroczy@gmail.com, 82
Davis-Stober, Clintin P.
stoberc@missouri.edu, 7, 44, 66, 93
Daw, Nathaniel D.
daw@cns.nyu.edu, 16
de Chiusole, Debora
deboratn@libero.it, 46
de Gardelle, Vincent
vincent.gardelle@gmail.com, 81
DeCarlo, Lawrence T.
decarlo@tc.edu, 37
Dechterenko, Filip
filip.dechterenko@gmail.com, 83
Dennis, Simon
dennis.210@osu.edu, 84
Deserno, Lorenz
sinembalta@gmail.com, 99
Diederich, Adele
a.diederich@jacobs-university.de, 31
Dimov, Cvetomir M.
cvetomir.dimov@unil.ch, 23
Dmitrieva, Julia A.
kostia1986@list.ru, 85
Doignon, Jean-Paul
doignon@ulb.ac.be, 41
Donkin, Chris
christopher.donkin@gmail.com, 65
Drayer, Ian
dinoian@yahoo.com, 84
Dunn, John Cameron
john.c.dunn@adelaide.edu.au, 34
Dutilh, Gilles
gilles.dutilh@gmail.com, 72
Dye, Melody
meldye@indiana.edu, 62, 84
Dzhafarov, Ehtibar N.
ehtibar@purdue.edu, 33

Hendrickson, Andrew
drew.hendrickson@adelaide.edu.au, 35
Hendrix, Peter
harald.baayen@uni-tuebingen.de, 39
Herce Castañón, Santiago
santiago.hercecastanon@psy.ox.ac.uk, 86
Hertwig, Ralph
hertwig@mpib-berlin.mpg.de, 25, 92
Herzog, Stefan M.
herzog@mpib-berlin.mpg.de, 56
Hidaka, Shohei
shhidaka@jaist.ac.jp, 63
Hilbig, Benjamin E.
hilbig@psychologie.uni-mannheim.de, 81
Hoffmann, Janina Anna
janina.hoffmann@unibas.ch, 87
Hohenstein, Sven
sven.hohenstein@uni-potsdam.de, 88, 94
Holschneider, Matthias
hols@math.uni-potsdam.de, 9
Horn, Sebastian
Sebastian.Horn@mpib-berlin.mpg.de, 88
Hotaling, Jared M.
jhotalin@indiana.edu, 70
Houpt, Joseph W.
joseph.houpt@wright.edu, 53

Ivanova, Galina
givanova@informatik.hu-berlin.de, 50–52
Iverson, Geoffrey
giverson@uci.edu, 14, 40

Jekel, Marc
mjekel@uni-bonn.de, 38
Jenny, Mirjam A.
jenny@mpib-berlin.mpg.de, 22
Johns, Brendan
johns4@indiana.edu, 56, 62, 84

Kachergis, George
george.kachergis@gmail.com, 60, 63
Kahana, Michael
kahana@psych.upenn.edu, 52
Kalish, Michael
kalish@louisiana.edu, 34
Kareev, Yaakov
kareev@vms.huji.ac.il, 25
Katsarska, Irina
irina_15_22@yahoo.com, 52
Katsikopoulos, Konstantinos
katsikop@mpib-berlin.mpg.de, 25, 36
Kellen, David
david.kellen@psychologie.uni-freiburg.de, 75, 81, 90
Kesselmeier, Miriam
kesselmeier@imbi.uni-heidelberg.de, 79
Khodadadi, Arash
arakhoda@indiana.edu, 13
Kiliç, Asli
kilicasli@gmail.com, 88
Kim, Woojae
wjkim0571@gmail.com, 22
Klauer, Karl Christoph
christoph.klauer@psychologie.uni-freiburg.de, 73, 75, 90
Kliegl, Reinhold
kliegl@uni-potsdam.de, 63, 74
Koop, Gregory J.
gjkoop@syr.edu, 59
Krügel, André
kruegel@uni-potsdam.de, 63, 89
Kuang, Xutao
xtk@bu.edu, 9
Kvam, Peter
kvam.peter@gmail.com, 12

Lagnado, David
d.lagnado@ucl.ac.uk, 38
Laubrock, Jochen
laubrock@uni-potsdam.de, 80
Lee, Michael D.
mdlee@uci.edu, 40, 82, 86, 91
Leite, Fabio
leite.11@osu.edu, 89
Lentz, Jennifer J.
jjlentz@indiana.edu, 53

Lerche, Veronika
veronika.lerche@psychologie.uni-heidelberg.de, 76
Leslie, David
david.leslie@bristol.ac.uk, 30, 44, 54, 66
Lewandowsky, Stephan
stephan.lewandowsky@uwa.edu.au, 28, 58, 64
Lewis, Nicholas J.
njlewis@indiana.edu, 59
Lim, Shiau Hong
shonglim@gmail.com, 44
Linzer, Julie
davekellen@gmail.com, 90
Little, Daniel R.
daniel.little@unimelb.edu.au, 33
Lloyd, Kevin
K.Lloyd@bristol.ac.uk, 30, 54
Logan, Gordon D.
gordon.logan@vanderbilt.edu, 17, 32
Love, Jonathon
jon@thon.cc, 32
Lu, Zhong-Lin
Lu.535@osu.edu, 85
Luan, Shenghua
luanshenghua@gmail.com, 55
Lubashevsky, Ihor
i-lubash@u-aizu.ac.jp, 68
Luhmann, Christian C.
christian.luhmann@stonybrook.edu, 75
Lukavsky, Jiri
lukavsky@praha.psu.cas.cz, 83

Müller, Hermann
hmueller@lmu.de, 32
Makarava, Natallia
natallia.makarava@gmail.com, 9
Malejka, Simone
malejka@uni-mannheim.de, 54
Malhotra, Gaurav
gaurav.malhotra@bristol.ac.uk, 44
Malmberg, Kenneth J.
malmberg@usf.edu, 43
Mante, Valerio
vmante@gmail.com, 20
Marewski, Julian N.
julian.marewski@unil.ch, 23
Marley, A.A.J.
ajmarley@uvic.ca, 29
Martignon, Laura Felicia
martignon@ph-ludwigsburg.de, 62
Martin, Jay
jbmartin@nyu.edu, 61
Mata, Rui
mata@mpib-berlin.mpg.de, 97
Matuschek, Hannes
hannes.matuschek@uni-potsdam.de, 74
Matzke, Dora
d.matzke@uva.nl, 19, 32, 64
McCausland, William J.
william.j.mccausland@umontreal.ca, 29
McRae, Ken
kenm@uwo.ca, 49
Meder, Björn
meder@mpib-berlin.mpg.de, 23
Merlone, Ugo
ugo.merlone@unito.it, 69
Michalkiewicz, Martha
michalkiewicz@psychologie.uni-mannheim.de, 90
Miller, Brent
brentm@uci.edu, 30, 91
Mittner, Matthias
mittner@uva.nl, 50
Moran, Rani
rani.moran@gmail.com, 32, 71
Morey, Richard D.
r.d.morey@rug.nl, 35, 80
Moshagen, Morten
moshagen@uni-mannheim.de, 74, 86
Murray, Richard F.
rfm@yorku.ca, 91
Myers, Nicholas
nicholas.e.myers@googlemail.com, 81
Myung, Jay I.
myung.1@osu.edu, 22, 43, 85

Narens, Louis
lnarens@uci.edu, 12, 70
Navarro, Daniel
daniel.navarro@adelaide.edu.au, 35
Nelson, Jonathan D.
jonathan.d.nelson@gmail.com, 23, 67
Neufeld, Richard W. J. (Jim)
rneufeld@uwo.ca, 61
Nilsson, Håkan
hakan.nilsson@psyk.uu.se, 22
Niv, Yael
yael@princeton.edu, 20
Nolte, Guido
g.nolte@uke.de, 100
Nosofsky, Robert
nosofsky@indiana.edu, 65
Noventa, Stefano
stefano.noventa@univr.it, 48

Oberauer, Klaus
k.oberauer@psychologie.uzh.ch, 64
Obermayer, Klaus
oby@ni.tu-berlin.de, 99
Oeztekin, Ilke
ioztekin@ku.edu.tr, 88
Osting, Braxton
braxton@math.ucla.edu, 84
Ostwald, Dirk
dirk.ostwald@mpib-berlin.mpg.de, 92

Palmeri, Thomas J.
thomas.j.palmeri@vanderbilt.edu, 17
Park, Sang Hyuk
sp46d@mail.missouri.edu, 93
Pauen, Katrin
pauenkat@informatik.hu-berlin.de, 49
Paul, Williams
Paul.Williams@newcastle.edu.au, 78
Pedersen, Arthur P.
pedersen@mpib-berlin.mpg.de, 40
Perfors, Amy
amy.perfors@adelaide.edu.au, 35
Pfeifer, Niki
niki.pfeifer@lrz.uni-muenchen.de, 68
Phillips, Nathaniel D.
phillips@mpib-berlin.mpg.de, 25
Pitt, Mark A.
pitt.2@osu.edu, 22, 43, 85
Pleskac, Tim
tim.pleskac@gmail.com, 12
Pooley, James
james.pooley@gmail.com, 40, 93
Popova, Anna
apopova2@illinois.edu, 45
Pritchett, Lisa M.
lmpritch@yorku.ca, 91
Purcell, Braden A.
braden.a.purcell@vanderbilt.edu, 17

Rabovsky, Milena
milena.rabovsky@hu-berlin.de, 49
Ramscar, Michael J. A.
ramscar@gmail.com, 39, 62
Ratcliff, Roger
ratcliff.22@osu.edu, 19, 98
Regenwetter, Michel
regenwet@illinois.edu, 44
Rehder, Bob
bob.rehder@nyu.edu, 61
Rexhep, Selim
srexhep@ulb.ac.be, 41
Rieskamp, Jörg
joerg.rieskamp@unibas.ch, 22, 27, 72, 87
Risse, Sarah
sarah.risse@uni-potsdam.de, 88, 94
Robusto, Egidio
egidio.robusto@unipd.it, 46–48
Rucci, Michele
mrucci@bu.edu, 9

Samanez-Larkin, Greg
gregoryrsl@gmail.com, 97
Schad, Daniel J.
danieljschad@gmail.com, 63
Schall, Jeffrey D.
jeffrey.d.schall@vanderbilt.edu, 17
Schooler, Lael J.
schooler@mpib-berlin.mpg.de, 23, 67

von Helversen, Bettina
bettina.vonhelversen@unibas.ch, 87, 97
Vorberg, Dirk
d.vorberg@uni-muenster.de, 15
Voskuilen, Chelsea Erin
voskuilen.2@osu.edu, 98
Voss, Andreas
andreas.voss@psychologie.uni-heidelberg.de, 76

Wabersich, Dominik David
dominik.wabersich@student.uni-tuebingen.de, 98
Wagenmakers, Eric-Jan
ej.wagenmakers@gmail.com, 18, 20, 32, 35, 64, 67, 97
Wang, Joyce
wang.1243@osu.edu, 12
Weidemann, Christoph
ctw@cogsci.info, 52
Wetzels, Ruud
wetzels.ruud@gmail.com, 67
Wichmann, Felix A.
felix.wichmann@uni-tuebingen.de, 7, 11, 96
Wickelmaier, Florian
wickelmaier@web.de, 60
Wiecki, Thomas
Thomas_Wiecki@brown.edu, 32
Wilke, Andreas
awilke@clarkson.edu, 97
Wollschläger, Lena Maria
l.wollschlaeger@jacobs-university.de, 31
Wong, John
jwong@mpib-berlin.mpg.de, 67
Wyart, Valentin
valentin.wyart@ens.fr, 81

Yamaguchi, Motonori
motonori.yamaguchi@Vanderbilt.Edu, 94
Yang, Cheng-Ta
yangct1115@gmail.com, 36
Yeung, Nick
nicholas.yeung@psy.ox.ac.uk, 18
Yu, Angela J.
ajyu@ucsd.edu, 27, 37

Zehetleitner, Michael H.
mzehetleitner@psy.lmu.de, 32
Zeigenfuse, Matthew D.
m.zeigenfuse@psychologie.uzh.ch, 43
Zeileis, Achim
achim.zeileis@uibk.ac.at, 61
Zelinsky, Gregory
Gregory.Zelinsky@stonybrook.edu, 10
Zgonnikov, Arkady
arkadiy.zgonnikov@gmail.com, 68
Zhang, Jun
junz@umich.edu, 13, 29
Zhang, Shunan
s6zhang@ucsd.edu, 27, 37

MONDAY (August 5th, 2013)

Time	Room: Bayes	Room: Euler	Room: Fechner
8:40	**Opening address** (Room: Helmholtz)		
9:00	**Wichmann:** Machine learning methods for system identification in sensory psychology (Room: Helmholtz)		
10:00	coffee break		
10:30	**Rucci:** Effects of microscopic eye movements on contrast sensitivity in humans and neurons	**Jenny:** The Similarity-Updating Model of Probability Judgment and Belief Revision	**Katsikopoulos:** Advances in Prescriptive Decision Theory
10:50	**Makarava:** Bayesian estimation of the scaling parameter of fixational eye movements	**Kim:** How PDP Models Learn Quasiregularity	**Phillips:** Social competition affects information search and choice
11:10	**Einhäuser:** Gaze in real-world scenarios: interaction of task and stimulus	**Nelson:** On optimality conditions for the likelihood difference heuristic	**Bhatia:** Implementing Heuristic Rules in Preference Accumulation Networks
11:30	**Zelinsky:** Eye can read your mind: Decoding gaze fixations to reveal categorical search targets	**Dimov:** Building cognitively plausible models of decision strategies in ACT-R	**Andraszewicz:** Why and How to Measure the Association between Choice Options
11:50	**Barthelmé:** Point process models for eye movement data	**Anders:** A cultural consensus theory model for the polytomous ...	**Zhang:** Cheap but Clever: Human Active Learning in a Bandit Setting
12:10	**Engbert:** Using spatial statistics of gaze patterns to model attentional selection	**Vandekerckhove:** Cognitive latent variable models	**Chechile:** Assessing Risky Weighting Functions via their Logarithmic Derivative Function
12:30	lunch break (JMP meeting: S13)		
1:50	**Narens:** Duncan Luce and the Foundations of Measurement	**Cook:** The Biasing Influence of Worldview on Climate Change Attitudes and Belief Polarization	**Gondan:** Simple correction methods for task completion times contaminated by errors, outliers ...
2:10	**Busemeyer:** Markov versus Quantum Random Walk Models of Decision Making	**Zhang:** Bayes Theorem, Mutual Information, and Shannon Source/Channel Coding: An ...	**Wollschläger:** The $2N$-ary choice tree model for N- alternative preferential choice—...
2:30	**Colonius:** Positive dependence via variability	**McCausland:** Bayesian Inference and Model Comparison for Random Choice Structures	**Matzke:** BEESTS: Software package for the Bayesian estimation of stop-signal reaction time ...
2:50	**Zhang:** Topological Characterization of Interval and Semi-Orders	**Leslie:** Rats in a T-maze: a Bayesian clustering model	**Moran:** Competitive Guided Search: Meeting the challenge ...
3:10	**Townsend:** Model Mimicry of Diffusion Processes by Independent-Channels Parallel Race Models	**Miller:** Differences between Observed and Latent Confidence in Rank Ordering	**Fific:** A snake wiggle of reaction time functions to indicate holistic perception
3:30	**Iverson:** A Representation Theorem for Symmetric ROCs	**Tauber:** An Integrative Bayesian Approach to Cognitive Modeling	**Dzhafarov:** Revealing mental processing architectures ...
3:50	coffee break		
4:20	**Smith:** Psychophysics and Response Time: Our Enduring Debt to Duncan Luce	**Dunn:** A statistical test of the dimensionality of the state-trace plot	**Yang:** Selective attention modulates the effect of contingencies on the perceptual decision process
4:40	**Steingrimsson:** Luce's Theoretical and Empirical Applications of Measurement Theory: The last ...	**Speekenbrink:** Considering the Null	**Hariskos:** Heuristic Decision Making in One-Shot Ultimatum Bargaining Games
5:00	**Vorberg:** Invariant deadline models for speed-accuracy tradeoffs ...	**Verhagen:** Default Bayes factors for crossed random effects designs	**Zhang:** Better safe than sorry: When superstition pays
5:20	**Suppes:** A challenge for neuroscience: How the brain can ... **Galanter:** Memories of My Friend	**Hendrickson:** Modeling the effect of hypothesis sparsity on confirmation bias	**DeCarlo:** On Relations among Decision Rules for the Same-different Task
5:40-7:30	**Poster Session** (Lobby)		

TUESDAY (August 6th, 2013)

Time	Room: Bayes	Room: Euler	Room: Fechner
8:40	**Daw:** Computational models of prediction learning: comparing ...	**Bramley:** Modelling active causal learning	**Lee:** Bayesian inferences for multidimensional scaling models
9:00	**van Vugt:** Relating neural and behavioral dynamics of decisional processes: from simple to more ...	**Jekel:** Comparing two classes of formal models of learning in probabilistic decision making	**Pedersen:** An Extension Theorem and a Numerical Representation Theorem for Qualitative ...
9:20	**Palmeri:** Modeling Neural Dynamics and Behavioral Dynamics ...	**Ramscar:** The myth of cognitive decline	**Rexhep:** The Semiorder Polytope
9:40	**Turner:** Constraining Cognitive Abstractions Through Bayesian Modeling	**Hamrick:** Inferring mass in complex physical scenes via probabilistic simulation	**Doignon:** Chains of biorders, interval orders or semiorders
10:00	coffee break		
10:30	**Summerfield:** Rhythmic fluctuations in information accumulation in the human brain	**Trueblood:** A Dynamic Dual-Process Model of Risky Decision-making	**Spoto:** Extracting a skill map from a data set: a KS construction methodology
10:50	**Steinhauser:** Evidence accumulation and the emergence of error ...	**Zeigenfuse:** A Weighted Sequential Sampling Model of Risky ...	**de Chiusole:** Modeling Missing Data in Knowledge Space Theory
11:10	**Ratcliff:** Single Trial Analysis of EEG in Perception and Memory	**Annis:** A Model of Positive Sequential Dependencies in Judgments of Frequency	**Anselmi:** An Evolving Computerized Adaptive Testing Procedure for Enhancing Individual ...
11:30	**Forstmann:** Practice in a Decision Making Task Induces Ultrafast Changes in Structural ...	**Cavagnaro:** Discriminating Among Probability Weighting Functions Using Adaptive ...	**Stefanutti:** Cognitive Diagnostic Models and Knowledge Space Theory: The non-missing link
11:50	**Mante:** Selective integration of sensory evidence by recurrent dynamics in prefrontal cortex	**Malhotra:** Decreasing bounds in sequential decision-making	**Noventa:** A perspective on Item Response Theory and Rasch Models based on the most ...
12:10	**Eldar:** The effects of neural gain on attention and learning	**Regenwetter:** QTest: Quantitative Testing of Theories ...	**Heller:** On the identifiability of probabilistic models ...
12:30	lunch break (JMP meeting: S13)		
1:50	**Rabovsky:** Simulating the N400 ERP component as semantic network error: Insights from ...	**Lentz:** Processing Characteristics of monaural and binaural frequency perception: Extending systems ...	**Alexander:** Stimulus Similarity in Continuous Recognition Memory
2:10	**Pauen:** EEG-Coupling Analysis via Circular Correlation Coefficients ? A Comparison with Conventional ...	**Lloyd:** Suboptimal or just parsimonious? The specificity of learned expectations in motion perception	**Ehresmann:** MENS, an integrative model for the development of higher cognitive processes
2:30	**Mittner:** Cross-modal detection of task-unrelated thoughts using Hidden Markov Models	**Malejka:** Continuous vs. Discrete Models of Signal Detection: An Exploration of the Subjective ...	**Ecker:** Implementing a consolidation mechanism into SIMPLE
2:50	**Heideklang:** Methodology for Adaptive Automatic Quantification of Brain Signals in the ...	**Luan:** A Signal Detection Model of Advice Taking	**Lewis:** Information Accumulation for Recognition: Dynamic Presentation and Diagnosticity
3:10	**Weidemann:** Explicit and implicit measures of memory strength	**Herzog:** Reverse-engineering decision makers? priorities using ...	**Koop:** Response dynamics as a measure of bias and strength ...
3:30	**Ivanova:** Analysis of Cognitive Evoked and Induced Potentials Based on Intrinsic Mode ...	**Shiffrin:** Modeling Semantic and Orthographic Visual Priming	**Cox:** Perceptual Similarity, Encoding Strategy, and Decision Dynamics in Recognition Memory
3:50	coffee break		
4:20-6:00	**Business Meeting** (Room: Helmholtz)		
6:00-6:30	**Transfer to Harbor** (S-Bahn)		
6:30-9:30	**Conference Dinner**		

WEDNESDAY (August 7th, 2013)

Time	Room: Bayes	Room: Euler	Room: Fechner
8:40	**Wickelmaier:** Investigating the effects of subject covariates in multinomial processing tree models by ...	**Dye:** What's in a name? Engineering memorable names with the tools of information theory	**Lewandowsky:** Rehearsal in working memory: Friend or enemy of retention?
9:00	**Neufeld:** Monitoring Clinical Treatment Response using ...	**Kachergis:** Towards a Cognitive Bayesian Model of Word Learning	**Wagenmakers:** Bayes factors for multinomial processing trees
9:20	**Martin:** Causal-knowledge and Information Search During Categorization	**Schad:** The zoom lens of attention: Simulation of text reading using the SWIFT model	**Donkin:** Discrete-Slots Models of Visual Working-Memory Response Times
9:40	**Martignon:** Fast and frugal trees compared with Bayesian Networks	**Kliegl:** Are Parafoveal Effects of Word Frequency and Predictability due to Distributed Processing ...	**Hemmer:** Modeling a non-monotonic relationship in single item recognition for continuous ...
10:00	coffee break		
10:30	**Davis-Stober:** A new perspective on noncompensatory decision-making: ... (Room: Helmholtz)		
11:30	**Floyd:** When two heads aren't better than one - the role of stimulus sensitivity and personality in ...	**Wong:** Adaptive stopping in secretary problems with real values instead of ranks	**Cadez:** A Complex Dynamical Order Memory
11:50	**Brown:** Evaluating Decision Maker "Type" Under p-additive Utility Representations	**Zgonnikov:** Fuzzy control, dynamical traps and virtual stick balancing	**Merlone:** A mathematical model of group dynamics in social dilemmas
12:10	**Steingroever:** Assessing Goodness of Fit for Reinforcement-Learning Models of the Iowa ...	**Pfeifer:** Mathematical philosophy meets mathematical psychology	**Hotaling:** Decision Field Theory-Dynamic: A Cognitive Model of Planning On-The-Fly
12:30	lunch break (JMP meeting: S13)		
1:50	**Narens:** Alternative Probability Theories for Decision Theory	**Singmann:** Comparing Models of Probabilistic Conditional Reasoning: Evidence for an Influence ...	**Lerche:** How Many Trials are Needed for a Robust Diffusion Model Analysis? A Comparison ...
2:10	**Usher:** Modeling confidence: The puzzle of resolution.	**Matuschek:** ANOVA Decomposition of Smoothing Splines	**Dai:** An extensive comparison of probabilistic models on ...
2:30	**Teodorescu:** Disentangling Decision Models: from Relative to Absolute Stopping Rules	**Auerswald:** A flexible approach to simulating non-normal data using a non-linear structural model	**Friedman:** Bias in preferred initial direction of arm movements induces a decision bias
2:50	**Dutilh:** Comparing Perceptual and Preferential Decision Making	**Kellen:** The flexibility of models of recognition memory: An analysis by the minimum-description ...	**van Ravenzwaaij:** Action Video Games Do Not Improve the Speed of Information Processing in ...
3:10	**Tsetsos:** Challenges for sequential sampling models: the influence of evidence variance on choices ...	**Luhmann:** The Predictive Accuracy of Intertemporal-Choice Models	**Heathcote:** Not all errors are equal: on the nature of slow and fast post-errors adjustments
3:30	**Closing address** (Room: Helmholtz)		