Contents

Welcome

Dear colleague,

We are happy to welcome you to the 44th annual meeting of the *Society for Mathematical Psychology* being held on the Medford campus of Tufts University. This year's conference features plenary addresses from Barbara Dosher, Yann LeCun, and the 2010 winner of the William K. Estes Early Career Award - Janne V. Kujala. There are also 3 invited symposia, 122 accepted talks and 19 posters. After the official close of the conference, there will be full-day workshop on July 19th on Multinomial Processing Tree Models (MPT).

Best regards,
The organizing committee: Robin Thomas, Richard Chechile, Richard Golden, Michael Lee & Annemarie Zand Scholten

Program Booklet Credits

General content; figures 1 – 3:	Conference Committee
Abstracts; figure 4:	Their respective authors
LaTeX-code generation, lay-out, cover:	Timo Kluck, Infty Advies (www.infty.nl)

General Information

Registration & Reception

The conference will be in several Tufts University buildings that are within 35 meters from each other. The main building is the Aidekman Arts Center on 40 Talbot Avenue. This building contains the Cohen Auditorium, and Alumnae Lounge as well as the Theater Lobby. The welcome reception and registration will be in the Alumnae Lounge on Friday, July 15th. The reception will be between 6:00-8:30. Registration on the other conference days will be in the Theater Lobby area. Some of the talks will also be in either the Distler Performance Hall in the Granoff Music Center at 20 Talbot Avenue or in the lecture hall in the Sophia Gordon East Building, which directly across the street at 15 Talbot Avenue.

Presentation Guidelines

Talks

Except for the plenary addresses, all the talks will be in one of three concurrent sessions. Many people will wish to hear specific talks and to shuttle among the parallel sessions. Consequently, it is essential for each session to run strictly on schedule and for the sessions to begin on time. For all the regular talks, the presentation time will be limited to a total of 20 minutes, which includes a five minute period for discussion. Talks will be strictly timed. **We ask either the author or the coauthor of the last paper in each session to be the session Chair and to keep time for the session.** Each session is relatively short and has either four or five talks. **Please install your talk on the computer in the room well before the beginning of the session.**There will be some assistance if needed for loading the talks on the computer. The computers in each presentation room will be a PC. Each morning there will be some light refreshments available from 8:00 to 9:00, so arrive early.

Posters

Poster presentations will be held on Saturday July 16th between 5:00 pm to 6:30 pm. The posters will be in the Theater Lobby area of the Aidekman Arts Center. Each poster board will have a letter identification as well as a number code. For example C #3 denotes poster board C in location "3."

Conference Banquet Dinner

The conference diner will be on Sunday July 17th between 6:45 to 9:00 pm. The diner will be in the Function Hall on 51 Winthrop

Street. To get to the diner from the conference meeting rooms, go down Talbot Avenue two full blocks until you get to Packard Avenue. Turn right on Packard Avenue and follow this street all the way to the end, which is at Winthrop Street. Turn right onto Winthrop Street and go a half block to 51 Winthrop Street. The walk across campus to the Winthrop Street Function Hall is about a five plus minute walk.

Lunch

Lunches are included for conference attendees. The lunch is located one block up Talbot Avenue in the DeWick-MacPhie Dining Hall, which is on the corner of Talbot and Latin Way. This dining hall is a cafeteria that is used mainly by students. There is a reasonable range of lunch choices available, and there is no limit regarding the quantity of food selected (same cost for all). There is a check-in staff person who controls access to the cafeteria. We will supply the names of the conference registrants to the dining staff. On Sunday, instead of a lunch, there is a brunch menu. There is a small conference room in the DeWick-MacPhie dining hall; this room is reserved for the *Journal of Mathematical Psychology Editorial Board* on Saturday and reserved for the *Society for Mathematical Psychology Executive Committee* on Sunday.

Internet Access

Wireless Internet will be available during the conference, **but it is important to register your computer prior to the beginning of the conference**. This point is especially important because it takes 24 hours for Tufts Computer Services to implement requests for internet access and because the first two days of the conference are over the weekend, so requests at that time might not be implemented until Tuesday July 19th, which is after the conference. **Fortunately you can register any time before the conference, and you do not have to wait until you are on the Tufts University campus to register your computer so it is recognized by the Tufts network.** You can register online at https://student.support.tufts.edu/connecting-conferences.php. Before you go on line, you should obtain the MAC address of your computer **Please note that MAC here stands for "Media Access Control", and it is universal for any computer regardless of manufacture.** To register your computer, there are specific steps to follow, depending on your computers operating system. Tips are available at: https://student.support.tufts.edu/connecting-computer-mac.php. **It is strongly recommended that you register as soon as possible in order to be assured that wireless access is available for when you arrive.**

Travel

From Boston Airport

The conference is at located on the Medford/Somerville campus, which is in the Western Boston suburbs. Also many of the recommended hotels are relatively near the campus. Consequently, it might be most

convenient to take a cab from the airport. There is cab waiting stand outside the terminal. The cab fare will depend on distance and time, a rough estimate for the cab fare is about $35 or more. Tufts University has three campuses in three, widely diverse locations, so be clear when directing the cab driver that it is the Medford/Somerville campus that you are going to.

There also is a lower cost (but a more lengthy – time wise) option using public transportation from Boston Logan Airport. The MBTA Silver Line bus (SL1) is at any terminal, and the Silver line can get you to South Station. At South Station take a Red Line subway or "T" heading in the direction of Alewife. If you are going directly to the Tufts University campus, then get off at the Davis Square stop. Exit the subway on the College Avenue side. Tufts University is a ten-minute walk (up College Avenue) away from the Davis Square subway stop. Alternatively from Davis Square you might also take either the #94 or #96 bus to the campus. If you are first going directly to your hotel, then ask your hotel for their recommended directions for getting to the hotel.

Amtrak/Bus from the South Station

For those who are traveling via train or bus to Boston, get off at the South Station Terminal. From here you need to either take a cab or the subway, which we call the "T", to get to the Tufts Campus or to your hotel. The Red Line subway can be taken directly from the South Station Terminal building. Take the Red Line in the direction for Alewife. If going directly to the Tufts University campus, then get off the Red Line train at the Davis Square stop. The University is a ten-minute walk (up College Avenue) from the subway exit. If going to your hotel, then find out from your hotel the best subway exit.

Traveling by Car

North If you are approaching on Routes 1, 95, 128 or 93, take Route 93 south to Exit 32, Medford Square. From the exit ramp, take the first right off the traffic circle, which is Route 60 west. At the second set of lights, bear left on Main Street and take an immediate right on to Route 16 west. Continue on Route 16 for approximately one and a quarter miles. An athletic field will appear on your right. At the third traffic light turn left onto Packard Avenue. You are now on the Tufts campus.

Northwest If you are approaching on Route 2 East, continue on Route 2, past the junction of Routes 2 and 95. If you are approaching on Route 3, take Route 95 south to Route 2 east (Exit 29A). At the junction of Routes 2 and 16, bear left through a full traffic light on Route 16 east. Take Route 16 east through two full traffic lights. You will see blue signs on the right for Tufts University. Follow the blue signs and take a sharp right up the hill on Powder House Boulevard. At the third traffic light turn left onto Packard Avenue. You are now on the Tufts campus.

West or Southwest If you are approaching on Routes 90 (Massachusetts Turnpike) or 95 take Route 95 north to Route 2 east (Exit 29A). At the junction of Routes 2 and 16, bear left through a full traffic light on Route 16 east and refer to directions in the preceding paragraph.

South or Boston If you are coming from

the south, take Route 3 north to Route 93 north. If coming from Boston, take Route 93 north. If coming from the airport, follow signs to Route 93 via the Sumner Tunnel. Take Route 93 north to Exit 31. Follow the exit ramp to Route 16 west and refer to directions in the first paragraph.

There is ample campus parking for conference registrants who are traveling by car, but ask for a parking pass when registering and picking up your name tag.

Workshop

Multinomial Processing Tree Models

The workshop will be conducted by William Batchelder, Richard Chechile, and Xiangen Hu and is designed to train workshop attendees on the details of the creation, estimation, validation, and utilization of MPT models and on the use of some software tools. The workshop is on July 19th and will be held in Cohen Auditorium in the Aidekman Arts Center at 40 Talbot Avenue on the Medford campus of Tufts University. Registration and payment for the workshop can be done via the main website for the conference (although it is also possible to register and pay for the workshop at the last minute – but "walk up" payment must be done by check because we will not have provisions for credit card payment.)

Boston - Venue

The Boston area is the home of a number of excellent universities, museums, theaters, tours, and gardens. For those who are interested in fine art, the Boston Fine Art Museum is unique and excellent. See the following websites for entertainment and tourist information while in Boston area:

http://www.bostonusa.com/visit
http://www.boston.com/thingstodo/

Places to Eat

A complete list of places to eat will be provided in the conference pack that will be distributed at registration time. For those staying off campus, the local hotels will also have suggestions for good restaurants. Near the campus, there are a number of college type pizza and sandwich places on the Boston Avenue side of the campus. Also there are several good restaurants in the Davis Square area, which is a ten-minute walk away from campus on College Avenue.

Abstracts For Plenary Talks

(Plenary abstracts organized by day)

(Plenary)

Saturday, 1:45

Plenary

Changing the State of the Observer in Visual Processing: Perceptual Learning and Attention. Barbara Anne Dosher, *University of California, Irvine*.

Processing of visual inputs is fundamental to how we interact with the world. The quality of performance depends in complex ways on properties of the stimulus as well as limitations in the observers system. It may also depend on the changing state of the observer, including changing states of perceptual learning, attention, adaptation, and others. This talk focuses on the phenomenon of perceptual learning, which improves perceptual task performance in several distinctive ways. External noise tests and noisy ideal observer models characterize the effects of perceptual learning (or attention) on an observer as a single system. Across a range of tasks, two independent mechanisms can be seen: tuning of the task relevant perceptual template to improve filtering (external noise exclusion) and enhancing the stimulus (reducing absolute threshold). Several technical properties eliminate classes of prior models. Performance signatures for observer models then generate constraints on more detailed models. At the next level, implementations of multi-channel sensory representations suggest that, for perceptual learning, both mechanisms may reflect re-weighting of information from early sensory codes. Principles of reweighting through augmented Hebbian learning provide an account of a range of phenomena in perceptual learning, including the roles of feedback, training accuracy, task precision, and transfer to related but different tasks. The framework provides a systematic framework to consider the joint effects of stimuli and tasks in perceptual learning.

(Plenary)

Sunday, 1:45

Plenary

Training Hierarchical Systems for Visual Perception. Yann LeCun, *Courant Institute, New York University*.

Over the last few years, a surprising convergence has occurred between research in computational visual neuroscience, visual psychophysics, object recognition with artificial vision systems, the branch of applied mathematics concerned with sparse representations of high-dimensional data, and a new sub-field of machine learning dubbed "deep learning".

The best artificial vision systems bear an increasingly strong resemblance with their natural counterpart, exhibit some of the

qualities and deficiencies of the human visual system observed by psychologists. Like their natural counterparts, these artificial systems relies heavily on learning (unsupervised and supervised), and use building blocks and architectural concepts borrowed from neuroscience. The architectures are multi-level stacks analogous to the V1-V2-V4-IT hierarchy, that includes modules such as highly-non-linear local feature detectors with sparse activations, divisive normalization modules that create competition between nearby feature detectors, and spatial pooling modules la complex cells to build invariance.

Training such multi-stage systems to produce a hierarchy of increasingly global and invariant representations requires new "deep learning" algorithms. A system will be described that that combines a phase of unsupervised learning based on sparse sparse coding and sparse dictionary learning, followed by a phase of supervised fine-tuning. Examples of such biologically-inspired vision systems will be described and demonstrated live, with applications to object recognition in natural images, object detection, and obstacle avoidance for mobile robots.

(Plenary)
Monday, 1:45
Plenary

Dependence of random variables on external factors: Selectivity and adaptive estimation. JANNE V. KUJALA, *University of Jyvaskyla*.

In this talk I will address two distinct topics to which I have contributed in the past five years. On an abstract level, both are related to the dependence of random variables on external factors.

The first part focuses on selectivity of the dependence. Given a set of observable random variables and a set of external factors affecting the joint distribution of the random variables, the influence of the factors on the observable variables is called selective if each factor influences only a certain corresponding random variable. Mathematical definition of the selectivity is considered and a systematic treatment of different (population level) tests of selectivity is given. A test can be constructed on any condition of the family of joint distributions (over all possible combinations of factor levels) that is predicted by the definition of selectivity but does not always hold in the absence of selectivity.

In the latter part of the talk, the focus is on estimation of the parameters of the statistical dependency of random variables on external factors. A theoretical review of Bayesian adaptive estimation is given, highlighting some recent developments. One such development is the novel framework where the observation of a random variable is associated with a certain random cost of observation that depends on the external factors. For example, the cost could be defined as the random time taken by each trial in an experiment, and one might wish to maximize the expected total "information gain" over as many trials as can be completed in 15 minutes.

Abstracts For Symposium Talks

(Symposium abstracts organized by day and presentation order)

(20)

Saturday, 9:00

Cohen

Twenty-five Years of General Recognition Theory: Approaches and Tools. Tamaryn Menneer, *University of Southampton*, Leslie Blaha, *Air Force Research Laboratory*, James Townsend, *Indiana University*. Symposium Overview: General recognition theory (GRT) is a multidimensional generalisation of signal detection theory, which allows the disambiguation of perceptual and decisional processes in the recognition of multidimensional stimuli. In particular, this framework allows the characterization of multiple sources of (in)dependence in the perceptual and decisional stages in the classification or identification of multidimensional stimuli. GRT is therefore an extremely powerful tool in many areas of cognitive psychology. The aim of this symposium is to increase the understanding and accessibility of GRT-based analyses by providing an overview of GRT, discussing techniques for experimental design, and presenting existing and novel analysis methods for a variety of classification tasks. Together, the presenters will illustrate the state-of-the-art and the future directions for the study of human observers through multidimensional signal detection theory.

(21)

Saturday, 9:20

Cohen

A Brief History of General Recognition Theory. F. Gregory Ashby, *University of California, Santa Barbara*. General recognition theory (GRT) was initially developed as an attempt to model perceptual dependencies between features during letter identification. Not surprisingly, the first published account of GRT proposed theoretical accounts of many perceptual independence-related constructs. In the ensuing 25 years, more than 350 articles have applied GRT to a wide variety of phenomena, including categorization, similarity judgment, decision making, face perception, recognition and source memory, response time modeling, attention, object recognition, speech perception, haptic perception, and the perception of sexual interest. Today, GRT is a widely used method for interpreting data from tasks that use stimuli varying on multiple dimensions. Two types of applications are common. One approach fits flexible GRT models to data (i.e., by estimating decision bounds and perceptual means, variances, and covariances), and another approach makes inferences based on GRT-derived summary statistics. Several freely available software packages facilitate

both of these approaches. Current research 1) extends GRT applications to new domains, 2) identifies the underlying neurobiological bases of GRT, and 3) develops process-level versions that associate GRT-defined constructs (e.g., perceptual separability) with certain properties of channel-based architectures and that extends GRT analyses to response times.

(22)
Saturday, 9:40
Cohen

Two hierarchical Bayesian General Recognition Theory models. Noah Silbert, *University of Maryland*. General Recognition Theory (GRT) provides a powerful framework for testing perceptual and decisional interactions between dimensions. However, in most previous work in the GRT framework, data are only analyzed at the individual subject level. This limitation may be overcome by hierarchical Bayesian statistical models, which enable simultaneous estimation of individual and group level parameters. Two hierarchical Bayesian models will be described. A very general multinomial-Dirichlet model enables hierarchical modeling of report (sampling) independence, marginal response invariance, and marginal d' and beta comparisons. The less general GRT model relies on the assumption of decisional separability and Gaussian perceptual distributions, but provides more straightforward results. Application of each model to data collected in a number of perceptual identification tasks will be presented.

(23)
Saturday, 10:00
Cohen

Some Notes on Multivariate Signal Detection Models and Extensions. Lawrence DeCarlo, *Columbia University*. Multivariate signal detection theory (MSDT) applies to situations where the events to be detected have multidimensional psychological representations and a response is given for each dimension, so that two or more responses are given on each trial (e.g., a concurrent rating task). MSDT accounts for possible correlations between responses via correlations in the underlying multivariate distributions. MSDT can also be applied when responses are missing, as in source monitoring studies where a source response is only given if the first response is that an event is a signal. MSDT has been placed within a general statistical framework, and so a well developed methodology is available; for example, the models can easily be fit with software for structural equation modeling. One way to extend MSDT is to allow for multivariate mixtures in the perceptual component of the model; this could occur, for example, because of lapses in attention. The decision component can also be extended in several ways. A simple extension is to allow for 'guessing'. Other extensions, however, raise some issues. For example, the use of likelihood ratio (LR) decisions raises complications with respect to estimation; this, as well as the use of LR decisions with missing responses, has not been discussed. Relaxing the assumption of 'decision separability', as in general recognition theory, raises issues with respect to identifiability. A useful first step for the analysis of multivariate data is to fit the MSDT model, examine parameter

estimates, and examine aspects of fit or any lack thereof.

(24)
Saturday, 10:45
Cohen

Probit model and tetrachoric correlation approaches to GRT analysis. Tamaryn Menneer, *University of Southampton*, Leslie Blaha, *Air Force Research Laboratory*, Michael Wenger, *University of Oklahoma*. We have developed two statistical techniques for General Recognition Theory (GRT) analysis with the future aim of applying them to situations where there are multiple GRT solutions for a single set of data. Firstly, however, our aim here is to evaluate these methods with respect to two existing analysis methods, including the non-parametric tests of Ashby and Townsend (1986) and the marginal parametric Theory of Signal Detection (TSD) measures of Kadlec and Townsend (1992). Our first new technique is a collection of probit models that can be estimated simultaneously across two dimensions (extension of DeCarlo, 2003). This approach allows direct estimation of bivariate correlations within perceptual distributions, which is not possible with marginal or non-parametric analyses. The second approach is an application of polychoric and tetrachoric correlation estimates (expanding the results of Ashby, 1988) both within and across all distributions. This method provides converging analyses to the probit models for identifying correlations between the dimensions within and across the stimuli in the GRT space. Both approaches will be contrasted with the non-parametric GRT and marginal TSD analyses to understand how they may improve efficiency and contribute converging evidence for identifying perceptual and decisional (in)dependencies from empirical data.

(25)
Saturday, 11:05
Cohen

Beyond identification: Extensions of the GRT to paradigms with fewer responses than stimuli. Robin Thomas, *Miami University*. In the original presentation of the General Recognition Theory and in many of its subsequent applications, the canonical task was a feature-complete factorial design. In this design, the set of objects under study are constructed by the factorial combination of discretely sampled stimulus attributes. The observer's task is to uniquely identify each object. While this design provides ample degrees of freedom to reveal perceptual interactions, it places a burden on the observer's response system (and working memory) especially when there are more than two attributes and/or values sampled along each attribute. Designs that place fewer response demands on observers include same-different, classification, and uncertainty paradigms. I review the theory outlining what can be inferred about perceptual representations in these designs and offer some concrete tools to accomplish this.

(26)
Saturday, 11:25
Cohen

General Recognition Theory Extended to Include Response Times: Predictions for a Class of Parallel Systems. Joseph Houpt, *Indiana University*, James Townsend, *Indiana*

University, NOAH SILBERT, *University of Maryland*. General Recognition Theory (GRT; Ashby & Townsend 1986) is a multidimensional theory of classification. Originally developed to study various types of perceptual independence, it has also been widely employed in diverse cognitive venues, such as categorization. The initial theory and applications have been static, that is, lacking a time variable and focusing on patterns of responses, such as confusion matrices. Ashby proposed a parallel, dynamic stochastic version of GRT with application to perceptual independence based on discrete linear systems theory with imposed noise (Ashby, 1989). The current study again focuses on cognitive/perceptual independence within an identification classification paradigm. We extend stochastic GRT and its implicated methodology for cognitive/perceptual independence, to an entire class of parallel systems. This goal is met in a distribution-free manner and includes all linear and non-linear systems satisfying very general conditions. A number of theorems are proven concerning stochastic forms of independence. However, the theorems all assume the stochastic version of decisional separability. A vital task remains to investigate the consequences of failures of stochastic decisional separability.

(27)
Saturday, 11:45
Cohen

From Deep Space 9 to the Gamma Quadrant! JAMES TOWNSEND, *Indiana University*. This allusion to these Star Trek vistas seems valid since the first quarter of a century of GRT has witnessed a growth from the original Ashby & Townsend 1986 Psychological Review article to several hundred studies. Deep Space 9 is kind of at the edge of the known universe and close to a black hole, which now appears traversable into the mysterious Gamma Quadrant. So it is with GRT. Greg Ashby has eloquently presented an impressive history of GRT in his lecture. My mission is to attempt to prophesy (and we all know how accurate future prognostications are – scientific soothsayers of an earlier day predicted we would all commute to and from work with our rocket-man backpacks by now –) some of the intriguing evolutions (beneficent mutations?) that GRT may undergo in the days and years to come.

(MS1)
Sunday, 9:00
Cohen

Recognition Memory is a Mixture of a Detect State and a Guess State. JORDAN PROVINCE, *University of Missouri*, JEFFREY ROUDER, *University of Missouri*. Recognition memory has typically been thought of as a signal-detection type process based on evaluation of a continuously-varying latent strength. Even more recent dual-process models are generalizations of this latent-strength theme, and the theme is popular because it is compatible with the curvilinear nature of extant ROC curves. Discrete-state model alternatives are rarely considered, and some authors mistakenly argue that they are incompatible with curvilinear ROCs. While this observation is correct for the most restricted class to discrete-state models, the more general and useful class, including low-threshold discrete-state models, predict

piece-wise linear ROCs that are compatible with observed data. To assess whether recognition memory is mediated by continuous latent strength or by discrete states, we examined confidence ratings distributions directly without recourse to ROCs. We ask whether the change in these distributions across a study-item repetition manipulation is better described as a shift (latent-strength account) or as change in mixing weights in a discrete mixture. Constraint is gained with the following key manipulation: we occasionally asked participants which of two new words were old, and their responses locate the distribution of confidence under guessing. The confidence ratings for other conditions are seemingly a mixture of this stable guessing state with an additional stable detect state. Formal model comparison is made by implementing both approaches as Bayesian hierarchical models, and the DIC model-comparison statistics supports the discrete-state account over the latent-strength account.

(MS2)
Sunday, 9:20
Cohen

What are the Boundary Conditions of Differentiation in Episodic Memory?. Adam Osth, *Ohio State University*, Simon Dennis, *Ohio State University*. One of the critical findings in recognition memory is the null list-strength effect (LSE), which states that strengthening items by extra study time or extra repetitions does not hurt the performance of other studied items. Episodic memory models were able to predict the null LSE by using the principle of differentiation, which states that repetitions of a single item accumulate into a single strong memory trace. A hypothesized boundary of the differentiation process is that repetitions of a single item in different contexts will create new traces. Three experiments were conducted that tested this hypothesis by repeating words across different study-test cycles rather than within a single study-test cycle and subsequently testing all the lists with an inclusion instruction. Results indicated that as the proportion of strong items increased, there was both a null LSE and a non-significant decrease in the FAR, which is contrary to the predicted strength-based mirror effect. These two results in tandem provide a challenge for differentiation models. These results were fit with the BCDMEM (Dennis & Humphreys, 2001) model with a modification to allow for noisy contextual reinstatement as well as the REM.4 model (Shiffrin & Steyvers, 1997), which contains a specified differentiation mechanism.

(MS3)
Sunday, 9:40
Cohen

Context in the Wild. Simon Dennis, *Ohio State University*, Vishnu Sreekumar, *Ohio State University* , Yuwen Zhuang, *Ohio State University*. Mikhail Belkin, *Ohio State University*. Recognition memory involves the ability to isolate the context in which a particular experience occurred. Most current models of recognition propose that a context cue is employed and, in the case of context noise models, interference from pre-experimental contexts is considered one of the primary determinants of performance. But our current ability to characterize context outside of the laboratory is embryonic. To address this situation,

we have participants wear a smart phone over a period of a week. The phone captures, accelerometer, orientation, gps and image data. In addition, we have subjects identify context breaks and to provide cues that they believe will allow them to retrieve these contexts at a later time. In this talk, I will describe what subjects believe constitutes a context, the distribution of cues they produce and how effective these cues are for later retrieval. I will also outline current attempts to automate context segmentation and cue generation using machine learning techniques in an effort to avoid the contamination of memory that occurs when participants tag their own data.

(MS4)
Sunday, 10:00
Cohen

State trace analysis of recognition memory. John Dunn, *University of Adelaide*, Andrew Heathcote, *University of Newcastle* , Simon Dennis, *Ohio State University*. Greig de Zubicaray, *University of Queensland*.

We use state trace analysis to test the proposition advanced by dual process models that recognition memory depends upon recollection and familiarity. In a major review, Yonelinas (2002) concluded that recollection and familiarity may be differentially affected by different experimental factors. According to the logic of state trace analysis, if this model is correct then the combination of factors that differentially affect recollection and familiarity should produce a two-dimensional state trace plot. We outline this logic and demonstrate the predicted outcome using simulated data from the dual process model. We also present the results of a series of experiments that combined number of study presentations which, according to Yonelinas' review, affects both recollection and familiarity, with each of six other factors which, based on the same review, primarily affect either recollection or familiarity. In each case, the results revealed a one-dimensional state trace plot. We discuss the implications of these results for models of recognition memory, the role of state trace analysis in comparing such models, and the apparently variant conclusions reached by Yonelinas (2002). [Reference: Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, **46(3)**, 441-517.]

(MS5)
Sunday, 10:45
Cohen

Output Interference in Recognition Memory. Amy Criss, *Syracuse University*, Kenneth J. Malmberg, *University of South Florida* , Tarun Gangwani, *Indiana University*. Richard Shiffrin, *Indiana University*. Context models assume that interference in recognition memory arises solely from the prior contexts of the test word: Interference does not arise from memory traces of other words (from events prior to the study list or on the study list, and regardless of similarity to the test item). Item noise models assume that interference arises from both similar contexts and similar items. Most tests of these models have focused on the structure of the study lists. We adopt a new approach of evaluating output interference, a decline in accuracy as a function of the words presented during test. Output interference is consistent with mod-

els that allow interference from words other than the test word, when each test produces a memory trace, and hence a source of interference. Models positing interference solely from prior contexts of the test word itself predict no effect of items presented during test, without added assumptions. Several new findings characterizing output interference in recognition memory will be presented.

(MS6)
Sunday, 11:05
Cohen

RTCON and the Diffusion Model. Jeff Starns, *University of Massachusetts Amherst*, Roger Ratcliff, *The Ohio State University* , Gail McKoon, *The Ohio State University*. Recognition memory theorists are realizing that receiver-operating characteristics (ROCs) are not a sufficient basis for model development. One way to address this concern is to expand models to additional forms of data, such as response time (RT) distributions. Ratcliff & Starns (2009) developed the RTCON model for ROCs and RT distributions in a confidence rating task. In the current work, we extend RTCON to a two-choice ("old"/"new") recognition task using a target proportion manipulation to define ROC functions. The design permitted competitive fits with the diffusion model, a well-established model of two-choice responding. Results showed that both models matched the empirical ROC functions. However, RTCON could not match the empirical RT distributions, resulting in a much better fit for the diffusion model. The results provide further confirmation that modeling RT distributions substantially increases model constraint beyond ROC data alone. Contrasting RTCON with the diffusion model suggests avenues for developing the former approach, hopefully resulting in a model that can accommodate ROCs and RTs from both two-choice and confidence rating tasks.

(146)
Sunday, 11:25
Cohen

Modeling Confidence and Response Time. Roger Ratcliff, *The Ohio State University*, Jeff Starns, *University of Massachusetts*. I describe a model for confidence judgments in perception and memory that deals with response confidence and response time distributions. The model assumes a distributed representation of memory strength and the areas between confidence criteria drive diffusion processes, one process for each confidence category. The new model updates an earlier model (Ratcliff & Starns, 2009, Psychological Review) with a new decision mechanism. The model is fit to recognition memory data including quantiles of RT distributions and ROC functions. The model fits data from individual subjects and accounts for puzzling nonlinear z-ROC functions.

(MS8)
Sunday, 11:45
Cohen

A Dynamic Activation Model for Accuracy and Response Time in Recognition Memory. Richard Shiffrin, *Indiana University*, Gregory Cox, *Indiana University*. Supposing episodic events (say on a list) consist of single instances of radically differing stimulus types (e.g. snowflakes, tunes, words, gabor patches, toasters, faces) how are decision criteria

chosen for subsequent recognition memory that are appropriate for the different stimulus classes? A standard approach to recognition memory decisions is rooted in signal detection: The test item is compared to the traces in episodic memory, producing a noisy 'familiarity' signal. Familiarity for targets and foils are presumed to be sampled from different distributions, and a decision criterion is chosen somewhere between the two distributions. For single classes of stimuli, a criterion can be learned, and for slightly different classes (e.g. high and low frequency words) models have been developed to predict observed mirror effects. It is, however, a mystery how appropriate criteria can be chosen for different stimulus classes when these are likely to differ from each other by large amounts, and there is no opportunity to learn them. We therefore propose a model in which the decision is based on the dynamic profile of activation or familiarity: In our modification of the standard REM model, familiarity (defined as 'odds' in REM) tends to rise for targets and fall for foils as features of the test stimulus are extracted. This is generally true regardless of such factors as asymptotic level of familiarity, number of extra list traces in memory, strength of storage, list length, and number of prior tests. Our new model therefore monitors moment to moment changes in odds, adding positive changes to one accumulator (leading to an "old" response) and negative changes to another accumulator (leading to a "new" response), with the decision amounting to the outcome of a race between the two accumulators. Simulation results show that the model provides a reasonable basis for decisions that is robust to differences in stimulus class and the experimental variables used in recognition memory studies.

(MS9)
Sunday, 12:05
Cohen

Modeling Recognition of Different Stimulus Classes with a Dynamic Activation Model. Gregory Cox, *Indiana University*, Richard Shiffrin, *Indiana University*. We carried out an episodic recognition memory study with radically varying stimulus classes of varying levels of background experience (e.g., familiar common objects and novel random dot patterns), with one item studied from each class. Given that novel objects are less familiar than common ones, a fixed criterion model of recognition decisions would predict strong biases to respond "old" to common items and "new" to novel items. Contrary to this prediction, the results are dominated by a mirror effect wherein novel items are less discriminable, but not uniformly rejected. We fit accuracy and response time with a new model that posits that recognition decisions are the product of dynamic changes in familiarity as features are extracted from the test probe, thus making the decision invariant with respect to the absolute familiarity of the item. Positive changes from one moment to the next are added to an "old" accumulator and negative changes to a "new" accumulator; the first accumulator to reach threshold governs the response and its latency. This model predicts and explains the observed performance in both accuracy and response time across disparate item classes as a function of the similarity within and between item classes.

(43)
Monday, 10:45
Cohen

Alternative Probability Theory for Subjective Probability and Decision. Louis Narens, *University of California, Irvine*. Two different approaches for generalizing probability that turn out to be closely related are considered: A measurement-theoretic approach in which a qualitative axiom of conditional probability is deleted and the resulting generalized probability functions are quantitatively described, and an approach where the classical Kolmogorov theory is reformulated so that the event space consists of open sets from a topology. Both approaches allow for probability to have, besides its usual measure of uncertainty, additional dimensions such as ambiguity and vagueness. Applications to subjective probability and decision theory are given that add structure and character to such phenomena as unpacking in support theory and the introduction of emotion into decision models.

(P2)
Monday, 11:05
Cohen

Model Selection Applied to Quantum Probability Models. Jerome Busemeyer, *Indiana University*, Richard Shiffrin, *Indiana University*, Zheng Wang, *Ohio State University*. We discuss the suitability of quantum probability theory for cognitive modeling and consider some practical issues regarding the way these models can be compared to traditional probability models. Do quantum probability models fit better simply because they are more complex? Do traditional methods for model comparison such as Bayesian Model Selection, Minimum Description Length, and Cross Validation pose special problems when employed for quantum probability models? These and other model selection issues will be addressed. Empirical results will be presented for a Bayesian model comparison between a quantum and a traditional decision model where both models were used to predict the results obtained from a large decision making experiment designed to study dynamic inconsistency.

(28)
Monday, 11:25
Cohen

Can We Do Without Sample Spaces?. Ehtibar Dzhafarov, *Purdue University*, Janne V. Kujala, *Jyvaskyla University*. In his epoch-making 'Foundations of the Theory of Probability,' 1933, Kolmogorov defined a random variable as a measurable function from a 'basic set,' included in a probability space, to a codomain included in a measurable space. (Kolmogorov's treatment of the codomain is confined to the Borel space on reals, but this is not essential.) The basic set was meant in Kolmogorov's theory to be the set of potential outcomes of an idealized experiment. Today we refer to the probability spaces on basic sets as sample spaces. Kolmogorov's approach ensures that joint distributions of random variables can be uniquely derived from their definitions as measurable functions: random variables A and B are either stochastically unrelated or have a joint distribution by the virtue of being measurable functions on the same set. An alternative approach is to acknowledge that a

joint distribution always depends on one's point of view: random variables A and B defined by their names and distributions are stochastically unrelated until we (essentially arbitrarily) define a new random variable C whose distribution is interpreted as the joint distribution of (A,B). We argue that this approach better suits applied purposes and makes the notion of a sample space dispensable, while preserving the rest of the mathematical apparatus of Kolmogorov's theory. This approach also alleviates the often expressed philosophical dissatisfaction with the fact that stochastic independence in Kolmogorov's theory is a 'numeric accident' rather than a fundamental relation.

(121)
Monday, 11:45
Cohen

The Assumptions of Bayes' Theorem for Conditional Densities.
Janne V. Kujala, *Univeristy of Jyvksyla*.
There is a trend towards increased use of Bayesian methodology in psychological sciences, both as models of human behavior and as general tools in modeling. One of the main tools of Bayesian statistics is Bayes' theorem for conditional densities. It holds very generally and is usually presented without any assumptions restricting its applicability. However, when considered in full measure-theoretic generality, the theorem does not, in fact, always hold. We characterize the conditions under which Bayes' theorem for conditional densities holds using several equivalent conditions and illustrate the nontriviality of the results using counterexamples. Although the assumptions are trivially satisfied in many practical applications,there are also highly abstract formulations used in psychology, where the conditions are not automatically satisfied. In particular, we consider some implications of the results to sequential Bayesian estimation.

(P3)
Monday, 12:05
Cohen

Applied Significance of the Foundations of Probability: General Discussion and Extended Audience Questioning

Abstracts For Talks

In alphabetical order by presenter

(118)
Sunday, 10:00
Distler

Applying a Bayesian measure of representativeness to sets of images. Joshua Abbott, *University of California, Berkeley*, Katherine Heller, *Massachusetts Institute of Technology*, Zoubin Ghahramani, *University of Cambridge*, Thomas Griffiths, *University of California, Berkeley*. How do we determine which elements of a set are most representative of that set? We extend an existing Bayesian measure of representativeness (Tenenbaum & Griffiths, 2001), which indicates the representativeness of a sample from a distribution, to define a measure of the representativeness of an item to a set. We show that the resulting measure is formally related to a machine learning method known as Bayesian Sets (Ghahramani & Heller, 2005). Building on this connection, we derive an analytic expression for the representativeness of objects described by a sparse vector of binary features. We then apply this measure to a large database of images, using it to determine which images are the most representative members of different sets. Comparing the resulting predictions to human judgments of representativeness provides a test of this measure with naturalistic stimuli, and illustrates how databases that are more commonly used in computer vision and machine learning can be used to evaluate psychological theories.

(31)
Monday, 9:40
East Sophia Gordon Hall Bldg.

Letters in Time and Retinotopic Space: A model of letter position and identity extraction. James Adelman, *University of Warwick*. Various phenomena in tachistoscopic word identification and priming (WRODS and LTRS are confused with and prime WORDS and LETTERS) suggest that position-specific channels are not used in the processing of letters in words. Previous approaches to this issue have sought alternative matching rules because they have assumed that these phenomena reveal which stimuli are good but imperfect matches to a particular word, such imperfect matches being taken by the word recognition system as partial evidence for that word. I present the new Letters in Time and Retinotopic Space model (LTRS), which makes the alternative assumption that these phenomena are caused by the differing rates at which different features of the stimulus are stochastically extracted. These extraction rates have their effect because the stimulus is ambiguous when (and only when) some features are missing from the percept. As such, only matches and mismatches need to be defined

by the matching rule. In consequence, different matching mechanisms can make identical predictions; conversely, priming data may not provide sufficient constraints to identify the matching mechanism. LTRS is successfully fitted to tachistoscopic forced-choice identification data both in terms of target duration and relationship to foil, taking accuracy as a fairly literal indicator of the information extracted. The same mechanisms are successfully applied to the prediction of form priming data with manipulations of prime duration and relationship to target. Such success supports the contention that the effects need not be interpreted in terms of a literal representation of cognitive similarity or distance.

(42)
Saturday, 10:00
Alumni

Cultural Consensus Theory: Estimating Consensus Graphs Under Constraints. Kalin Agrawal, *University of California, Irvine*, William Batchelder, *University of California, Irvine*. Cultural Consensus Theory (CCT) consists of cognitive models for aggregating the responses of informants to test items about some domain of their shared cultural knowledge. This paper presents a model where the test items concern ties in a complete signed graph. Informants provide dichotomous 'plus' or 'minus' responses to a possibly incomplete set of all pairs of nodes in a graph. The goal is to aggregate these responses to obtain information about the consensus signed graph under the constraint that the graph satisfies the condition of balance due originally to Heider. A balanced complete signed graph requires that the nodes of the graph can be partitioned into two sets, where all ties within a set are positive and all ties between sets are negative. We assume that informants respond according to a standard CCT model for dichotomous responses, so their responses may not satisfy the constraint of balance. Joint and marginal posterior distributions for the consensus complete balanced signed graph, as well as informant competencies and biases are all estimated using Markov Chain Monte Carlo methods via JAGS, a general purpose Gibbs sampling tool for graphical models. We apply the model to simulated data as well as real data involving a social network survey designed to mitigate possible dependencies in within-informant responses. Analysis of the dataset suggests that an incomplete pairwise survey design can provide sufficient data to recover accurate information about the latent pairwise ties between the graph nodes as well as the informant abilities and biases.

(51)
Sunday, 3:10
Alumni

A Bayesian Model of Saccadic Timing. Cordelia Aitkin, *Rutgers University*, John Wilder, *Rutgers University*, Eileen Kowler, *Rutgers University*. Many models of saccadic eye movements describe where people choose to fixate, neglecting the control of saccadic timing. Timing may be under immediate control, with a new saccade triggered when enough information is acquired from the fixated location, or controlled on the basis of expected task difficulty. The latter option is less demanding, but could lead to timing errors. To distinguish these alternatives, sub-

jects judged the mean location (relative to a reference line) of clusters of accumulating dots. A dot was added to the display every 50-200 ms and remained visible until a saccade was made out of the cluster. Task difficulty was controlled by the distance between the mean and the reference line. Results showed a strong effect of context on fixation times when two levels of difficulty were randomly intermixed within a block of trials. A Bayesian observer model was fit to the data by maximizing the likelihood of the distribution of dwell times given three model parameters: decision criterion, SD of the prior distribution of dot locations, and the mean of an exponential 'stopping function' (which allowed early termination of a fixation). The model reproduced the fixation times and the accuracy of judgments, as well as the effects of context. The stopping parameter was relevant only under conditions where performance efficiency was low (multiple clusters; high rate of dot appearance). These results support the use of strategies of saccadic timing that take into account recent history in order to optimize performance accuracy while reducing immediate processing demands.

(168)
Monday, 12:05
East Sophia Gordon Bldg.

Modeling the Effect of Item Similarity on Sequential Dependencies in Recognition Testing. Jeff Annis, *University of South Florida*, Kenneth J. Malmberg, *University of South Florida*. Assimilation occurs when the response on the current trial n, is positively correlated with the response on trial $n-1$. Although, assimilation has been observed in a wide range of perceptual paradigms, Malmberg, Annis and Hayward (submitted) found that assimilation also occurs in recognition tasks. Assimilation was modeled in the REM framework by assuming that features that represent the current test item in a retrieval cue carry over from the previous retrieval cue (Shiffrin & Steyvers, 1997). The model predicts that item similarity will therefore have positive effects on assimilation and negative effects on recognition accuracy. To investigate these predictions, we manipulated the similarity of the stimuli by presenting either landscape photos (high similarity) or photos of everyday objects such as shoes, cars, etc (low similarity). Similarity was modeled by assuming either that the item representations share a proportion of features or by assuming that the exemplars from different stimulus classes vary in the distinctiveness or diagnosticity.

(69)
Saturday, 10:45
Distler

A Dutch Book Argument for the Situation-Specific Rationality of Non-Probablistic Degrees of Belief. Donald Bamber, *University of California, Irivine*. In their standard form, Dutch Book arguments are arguments concerning monetary bets; they have been used to justify the assertion that rational degrees of belief must obey the laws of probability, in particular, the law of additivity which states: If A and B are incompatible propositions, then $DegBel(AorB) = DegBel(A) + DegBel(B)$. A generalized Dutch Book argument is presented here that is concerned with transactions of a resource that combines via a rule that

need not be additive. It is shown that rational degrees of belief must combine via the same rule by which the transacted resource combines. If the resource combines additively, as in the case of money, then rational degrees of belief must combine additively. But, if the resource combines non-additively, then rational degrees of belief will combine non-additively. Furthermore, in some cases, no monotonic transformation of rational degrees of belief will combine additively. What these results show is that, even though particular degrees of belief in particular propositions are rational in one situation, the same degrees of belief in the same propositions need not be rational in another situation.

(37)
Saturday, 9:40
Alumni

Cultural Consensus Theory: Comparing Different Concepts of Cultural Truth. William Batchelder, *University of California, Irvine*, Royce Anders, *University of California Irvine*. Cultural consensus theory (CCT) consists of cognitive models for aggregating the responses of 'informants' to test items about some domain of their shared cultural knowledge. Each model specifies parameters designed to represent the unknown, consensus truth of each item. We compare two CCT models for the case where informants' must give a 'true' or 'false' answer to each item. The standard CCT model for this case, called the General Condorcet Model (GCM), represents cultural truth in two-valued logic. In essence the GCM has the structure of a standard signal detection model except the culturally correct answers are latent, and the hit and false alarm probabilities are heterogeneous across informants. This paper proposes a new CCT model, called the Latent Truth Model (LTM), where truth is represented as a parameter in a latent truth continuum [0,1]. The model assumes that an informant draws a latent value from a beta distribution centered at an item's latent truth, and with a variance that depends on the informant's cultural competence. A true response is made iff the latent value for an item is larger than the informant's threshold value. Inference for both models is Bayesian using MCMC samplers. The two models are compared analytically, on simulated data, and on real data. The GCM is a latent class model whereas the LTM is a latent trait model; however, despite their different representations of cultural truth, they both deliver similar interpretations of data in terms of cultural consensus and informant competence and bias.

(135)
Saturday, 4:30
Cohen

Partial Least Squares-Correspondence Analysis (PLS-CA): A new approach to link measures of cognition and genetics. Derek Beaton, *The University of Texas at Dallas*, Herve Abdi, *The University of Texas at Dallas*. Traditional descriptive factor-based multivariate methods analyze one set of variables. However, in many studies the goal is to describe and analyze the information common to two or more sets of variables. One such study, the Alzheimer's Disease Neuroimaging Initiative (ADNI), uses a wide variety of nominal (i.e., qualitative) behavioral (e.g., neuropsychological and cognitive batteries) and ge-

netic measures. An obvious research question is to extract the information common to these two sets of variables. A standard approach to analyze two sets of variables is Partial Least Squares Correlation (PLSC), but (as we show) this approach used with nominal variables can create spurious conclusions .In order to analyze qualitative variables, we adapted PLSC for nominal data. This new approach, called PLS-CA, integrates Partial Least Squares and Correspondence Analysis (which is analogous to principal component analysis for nominal variables). Furthermore, we extend the PLS-CA framework to predict group membership (e.g., clinical group). This new technique, called Discriminant PLS-CA reveals factors common to two nominal data tables, while accounting for a priori discriminant information for observations. Inferential steps in PLS-CA includes non-parametric cross validation techniques such as permutation tests, and bootstrapping. In this talk we explore the theoretical aspects of PLS-CA and illustrate PLS-CA with cognitive and genetic data from the ADNI project.

(131)

Monday, 9:00

East Sophia Gordon Bldg.

Empirical benchmarks for a rational model of eye movement control in reading. Klinton Bicknell, *University of California, San Diego*, Roger Levy, *University of California, San Diego*. We provide a rational framework for understanding eye movement control in reading, in which the task of reading is taken to be one of sentence identification. Specifically, in this framework readers move their eyes to obtain noisy visual input, which they combine with probabilistic language knowledge through Bayesian inference to yield gradient posterior beliefs about sentence form and structure. We determine optimal behavior within this framework, with respect to reader goals, by using optimization techniques to find the most efficient eye movement policies within parameterized policy families. Simulations with a model using these optimal policies reveal that the framework provides a natural account of many effects of linguistic variables such as word frequency, predictability, and length on measures including fixation durations, word skipping probabilities, and refixation rates. This contrasts with current leading models of eye movement control in reading (e.g., Reichle et al., 1998, 2009; Engbert et al., 2002, 2005), which account for these phenomena by directly stipulating the shape of the effects of these variables on word processing rate functions. The framework thus provides an answer to the call to incorporate more detailed models of lexical processing into models of eye movement control in reading (see discussion in Reichle et al., 2003). Finally, we demonstrate that the framework provides a new explanation for why readers regress back to previous words: we show that reader confidence about previous words will sometimes fall because of new input, and in this case, that it is a rational reading strategy to regress.

(91)

Sunday, 9:40

Alumni

The Proportional Reversed Hazard Rate Model Offers a Statistical Test of Workload Capacity. Leslie Blaha, *Air Force Research Laboratory*, Katheryn

Farris, *Air Force Research Laboratory*. We introduce a new statistical test of the capacity coefficient measure of workload capacity based on the statistical properties of the proportional reversed hazard rate model (PRHRM). The reversed hazard rate function of a random variable $r(t)dt$ is the conditional probability that some process has failed in the infinitesimal interval around time t, given that it failed at or before t. Well known in reliability engineering, the reversed hazard function has found recent applications in the modeling of response time (RT) data. In particular, Townsend and Wenger (2004) introduced a capacity coefficient for exhaustive processing, $C(t)$, to characterize the behavior of individual channels under changes in cognitive workload. $C(t)$ is defined as the ratio of the summed cumulative reversed hazard functions of individual channels operating alone, which is the prediction of an unlimited capacity independent parallel (UCIP) model, to the observed cumulative reversed hazard function of n channels operating together. If the system is behaving like an UCIP model, then $C(t) = 1$.Gupta and colleagues (Gupta & Gupta, 2007; Gupta & Wu, 2001) defined PRHRM, where two random variable X, Y satisfy PRHRM if the ratio of their reversed hazard rate functions is equal to a proportionality constant $\theta > 0$. Let X be the RT of an individual channel and Y be the RT of all n channels. Assuming the individual channels are independent and identically distributed, we present a test of the null hypothesis that $\theta = n$ or equivalently, $C(t) = 1$.

(46)
Monday, 3:50

Distler

A Computational-level Explanation of the Speed of Goal Inference. Mark Blokpoel, *Radboud University*, Johan Kwisthout, *Radboud University*, Todd Wareham, *Memorial University of Newfoundland*, Theo van der Weide, *Radboud University*, Iris van Rooij, *Radboud University*. The ability to understand the goals that drive another person's actions is an important cognitive and social skill. This is, however, no trivial task, because the one and the same action can be explained by many different goals (e.g. one may wave ones arm to hail a cab or to swat mosquitoes). To explain how people perform this abductive inference, Baker, Saxe and Tenenbaum (2007 & 2009) proposed a computational-level theory that formalizes goal inference as Bayesian inverse planning (BIP). Although Bayesian models are very successful in characterizing cognitive capacities in various domains, it is also known that general Bayesian inference (whether exact or approximate) is computationally intractable (NP-hard). The intractability of the BIP model contrasts with the observation that people can make goal inferences quickly under real-world conditions. We investigate how the BIP model can nevertheless explain how people are able to make goal inferences quickly. This can be done by taking situational constraints explicitly into account in the model. We present a methodology—adapted from theoretical computer science—to identify constraints of situations that render the model tractable. We discuss the implications of our findings and we reflect on how the methodology can be applied to alternative models of goal in-

ference and Bayesian models in general.

(17)
Saturday, 3:10
Alumni

Analyzing test-taking behavior: Prospect Theory meets Psychometric Theory. David Budescu, *Fordham University*, Yuanchao Bo, *Fordham University*. There is a long tradition of applying 'corrections for guessing' when scoring multiple-choice tests. Budescu and Bar-Hillel(1993)analyzed these procedures and concluded that they are misguided and based on naive and simplistic model of behavior. Recently, Espinosa and Gardeazabal (2010) proposed a new 'optimal' correction for guessing that is based on a decision theoretical analysis of the choice to answer or omit items when one has only partial information. In this paper, we propose a different instantiation of such a model in which we invoke more realistic assumptions about the behavior of the Test Takers(TTs). The model combines elements from Item Response Theory(IRT) to describe the tests and Behavioral Decision Theory (BDT) to describe the TTs. We use this model to analyze the consequences of applying different penalty levels on the performance of TTs with different (a)attitude to risk, (b)levels of loss aversion and (c)accuracy of estimation of the degree of their knowledge (calibration).Our analysis shows that penalties for incorrect answers have detrimental effects and are undesirable for both TTs and the Test Makers. The penalty affects differentially TTs that vary along variables that are irrelevant to measurement of ability, so the risk averse, loss averse and overly conservative TTs are penalized disproportionately, while risk seekers and overconfident TTs are less affected. And, the distributions of estimated scores are biased, display higher variance and more skewed as a function of the severity of the penalty.

(35)
Sunday, 11:25
Alumni

Bayesian models for learning multiple related categories. Kevin Canini, *University of California, Berkeley*, Thomas Griffiths, *University of California, Berkeley*. Traditional models of human categorization, such as prototype and exemplar models, typically treat categories in isolation, building up each category's representation using only the observations from that category. However, common sense suggests that people draw on a large amount of prior knowledge when they perform a task such as learning a new category. In particular, if categories have certain commonalities or are related to each other in a structured way, then previously-learned categories can reveal information about how new categories will tend to be composed. We describe a Bayesian model of categorization, the hierarchical Dirichlet process (Teh et al., 2006), as well as an extension of it that we call the tree-HDP. These models are able to recognize and exploit commonalities and structured relationships between multiple categories, effectively increasing learning speed and accuracy. In particular, the HDP represents categories as mixture models where each component is potentially shared among any subset of the categories. In this way, if a cluster of objects appears in

multiple categories, this information can be shared across categories instead of having to be relearned. The tree-HDP captures more structured relationships between categories that are organized in hierarchical taxonomies. We first review prior work in which the HDP is used to demonstrate transfer learning effects between multiple categories. We then describe an experiment in which participants learn a hierarchical taxonomy of categories. We show that human learners and the tree-HDP model are both able to successfully learn the categories and reconstruct the correct taxonomical structure.

(45)
Saturday, 11:25
Distler

Adaptive Sampling of Information During Perceptual Decision Problems. Thomas Cassey, *University of Bristol*, David Evens, *University of Bristol*, Casimir Ludwig, *University of Bristol*, James Marshall, *University of Sheffield*, Rafal Bogacz, *University of Bristol*. During decision making, cognitive, sensory and physical restrictions often prevent the simultaneous extraction of information about all of the available alternatives. In such scenarios, the decision maker must decide how to sample the available sources of information in order to optimise their performance We consider such a scenario in the form of a relative motion discrimination task in which participants are presented with two moving dot patterns with different levels of noise and must identify which pattern moves clockwise relative to the other. The total time available for the decision is fixed and participants are free to observe the sources of information, subject to the restriction that only a single source can be observed at a given instant in time. This condition is enforced using eye tracking to control stimuli activation. To interpret the experimental results, a number of ideal observer models, with different assumptions of prior knowledge, were used to qualitatively analyse and predict participant behaviour. The models show that it is the level of noise in the stimuli, rather than direction of motion, that should influence the active sampling strategy, with a larger portion of time spent viewing the noisier alternative. Second, the models predicted a specific relationship between the level of noise in the stimuli and the expected number of times participants should switch between observing the two alternative stimuli. Both predictions were substantiated in the experimental data, suggesting that humans adapt their sampling strategy based on the uncertainty of the available sensory evidence for decision-making.

(89)
Saturday, 10:00
Distler

An adaptive experiment to assess probability weighting functions. Daniel Cavagnaro, *The Ohio State University*, Richard Gonzalez, *University of Michigan*, Mark Pitt, *The Ohio State University*, Jay Myung, *The Ohio State University*. In cumulative prospect theory (CPT), distortions of the probability scale are modeled with a probability weighting function. While there is general consensus about the qualitative shape of this function, numerous mathematical forms have been proposed, including Tversky and Kah-

neman's original one-parameter version, Prelec's axiomatically derived formulations, and a linear-in-log-odds function. Do these different functional forms make a difference? Do the predictions of CPT change when different assumptions are made about the mathematical form of the weighting function? To answer these questions, we conduct simulation experiments using an adaptive experimental design algorithm. The algorithm uses active learning to select new decision stimuli based on the responses to previous stimuli, and successfully identifies situations in which these qualitatively similar weighting functions yield contrasting choice predictions.

(85)
Monday, 9:20
Cohen

The decision process of detecting changes in first- and second-order orientations. Wen-Sheng Chang, *National Cheng-Kung University*, Yi-Jung Wu, *National Cheng-Kung University*, Cheng-Ta Yang, *National Cheng-Kung University*. Visual environment contains multiple levels of orientation information. First-order stimuli are processed through a conventional linear filtering stage for extraction of orientation information, whereas second-order stimuli are processed through a non-linear filtering stage. A vast amount of studies have shown that first- and second-order orientations are processed by independent parallel mechanisms. However, recent studies found that these two levels of information can be conjointly encoded for the later orientation discrimination. Due to the inconsistency, this study considered the general problem of how first- and second-order orientations are processed and interact on discrimination. We followed the suggestions from the system factorial technology (SFT, Townsend & Nozawa, 1995) to design the experiment, analyze data, and make inferences. Using a change detection task, participants were required to detect changes in the carrier (luminance-defined orientation), envelope (contrast-defined orientation), or both of a gabor patch. Results showed that three observers adopted parallel processing and followed a self-terminating rule to detect the multiple orientation changes. These results suggested that two levels of orientation information are processed independently and in parallel at the discrimination stage of processing. Activations from independent channels race for a decision. When either of the activations reaches the decision criterion, a change is detected. The null coactivation implies that different levels are not integrated before a decision, ruling out the possibility that they are coactively processed for discrimination. These findings suggest that the comparison outputs from first- and second-order orientation channels are processed in parallel for a detection decision.

(111)
Sunday, 3:50
Cohen

A Hazard and Reverse Hazard Examination of Recognition Memory Foils. Richard A. Chechile, *Tufts University*. Although many models of recognition memory concur that the representation of (old) items or targets is as a mixture of processes or distributions, these models, nonetheless, assume that the representation for new items or foils is characterized as a single uni-

modal distribution. However, if a participant is able to retrieve information about the memory targets, then foils can be rejected. The rejection of a foil is not because of a weak familiarity value produced by the foil, but because the participant knows what the targets are and therefore knows that the foil should be rejected. This knowledge-based foil recognition is, in fact, a feature of some multinomial processing tree models of recognition memory. Although knowledge about the target items in foil recognition is plausible, it is difficult for a signal detection representation of foils to be treated as a mixture of processes or distributions and still remain an identifiable model. Hence, the theoretical model for the foils is a critical issue in recognition memory. If evidence were provided that foil recognition involves a mixture of processes or distributions, then it would be a challenge for a number of signal-detection models of recognition memory. Hazard and reverse hazard functions are powerful tools for the detection of mixtures. In this paper, hazard and reverse hazard functions are used to examine the properties of foil recognition. A consistent pattern is reported here indicating that the foil distribution is not a homogeneous distribution but instead is a mixture of processes.

(112)

Monday, 11:45

East Sophia Gordon Bldg.

Learning hidden structure for cognitive control. ANNE COLLINS, *Brown University*, MICHAEL FRANK, *Brown University*. Cognitive control relies on the selection of hidden variables defining current contingencies, or task-sets. How this hidden structure is acquired in non-instructed learning situations is poorly understood, and modeling and behavioral research has only investigated the question in the presence of explicit incentives for hidden structure. We explore subjects propensity to naturally structure information while learning. To this end, we submitted subjects to a stimulus-action associations reinforcement learning task. Crucially, learning phase performance was not cued toward and could not benefit from a structured representation of the task rules. However, a following transfer phase allowed to test for earlier building and reuse of such structure. A new learning and decision model based on non-parametric hidden Markov model framework allowed us to make predictions on behavior and individual differences. It was pitted against other existing flat or structured learning models. As predicted by our model, behavioral results showed a significant transfer effect, indicating selection of hidden representation of learned rules. Pre-transfer task-switch costs allowed us to characterize subjects individual structures, and predicted subsequent transfer effects and errors repartition. Only the proposed model was able to account for all observed effects, including individual differences. This study thus shows that subjects have a propensity to build hidden structure regardless of its immediate utility (or even potential cost) for learning. Our model proposes a tractable approximate optimal inference framework that accounts for this hidden structure learning. We also extend the Basal-Ganglia Prefrontal Cortex neural network gating model to implement this structure learning.

(61)

Saturday, 3:50

Distler

Optimal time windows of audiovisual integration. HANS COLONIUS, *Oldenburg University*, ADELE DIEDERICH, *Jacobs University Bremen*. According to the 'time window of integration' hypothesis,stimuli from different sensory modalities must not be presented too far apart in time in order to be integrated into a multisensory perceptual event. Empirical estimates of time window width differ widely,however, ranging from 40 to 600 ms depending on context and experimental paradigm. Searching for a theoretical derivation of window width, Colonius and Diederich (*FrontIntegr Neurosci* 2010) developed a Bayesian framework with a decision rule based on the prior probability of a common source, the likelihood of temporal disparities between the unimodal signals, and the payoff for making right or wrong decisions. Here this is extended to the *focused attention* task where subjects are asked to respond to signals from a target modality only. Evoking the time -window - of-integration (TWIN) model an explicit expression for optimal window width is obtained. The approach is probed on two published focused attention studies. The first is a saccadic reaction time study assessing the efficiency with which multisensory integration varies as a function of aging. Although the window widths for young and older adults differ by nearly 200 ms, neither of them deviates significantly from their optimal values. In the second study, head saccadic reactions times to a perfectly aligned audiovisual stimulus pair had been shown to depend on the prior probability of spatial alignment. Intriguingly, they reflected the magnitude of the time window widths predicted by our decision theoretic framework.

(64)

Saturday, 4:10

Alumni

Value and Stage Together May Predict Behavior. MICHAEL COMMONS, *Harvard Medical School*. Accounts of behavior have been split between behavioral and cognitive paradigms. This presentation integrates the two through value, as measured in behavioral accounts, and stage, as measured with the Model of Hierarchical Complexity. Each of these constructs consists of a matrix. The Value matrix has a number of vectors. The overall value vector includes the valuation of all outcomes of activities in an organism's niche. For humans, the 6 factors of the Holland Codes describe such valuations, not including the primary reinforcer valuations. The second value vector in this matrix is the discounting-difference ratio between change in the overall value vector and delta t (time) as in Commons-Mazur's discounting equation. The third vector is the change in differences in value over time, or risk. For the Stage (second) matrix, the first vector consists of the variable numbers of tasks associated with each separate valuation factor from the value matrix. The order of hierarchical complexity of tasks accounts for the largest proportion of task difficulty variance. The second vector in this matrix is Stage, which is the measure of performance in meeting difficulties of a particular task. This stage of performance accounts for the largest amount of variance in measures such as economic success and awarding of malpractice judg-

ments. A mathematical account of the value and the stage matrices and how they interact to predict behavior will be given.

(114)
Saturday, 3:30
Cohen

A New Perspective on Power and Replicability. Clintin Davis-Stober, *University of Missouri*. Social scientists are currently facing a quantitative crisis. Upon attempted experimental replication, many thought-to-be established effects are either diminishing in magnitude or disappearing altogether (Schooler, 2011). Peer-reviewed journals are rife with contradictory findings, potentially attributable to grossly underpowered studies that result in the spurious rejection (or acceptance) of various hypotheses (e.g., Maxwell, 2000; Ioannidis, 2005; 2008). In this paper, we present a new perspective on experimental power and replication that is not based upon the common Null Hypothesis-Testing Framework (NHTF). We present a new statistic for use within the liner model that measures the amount of information contained in a given sample. We demonstrate how this statistic can be used to determine whether inferences based on Ordinary Least Squares (OLS) estimation are justified.

(97)
Sunday, 4:30
Cohen

Feature source confusion and discounting in both short-term priming and co-temporal flanking. Stephen Denton, *Indiana University*, Richard Shiffrin, *Indiana University*. Visual identification of briefly presented target words is affected by the presence of distractors that can take the form of prime words that immediately precede the targets temporally, flanker words that are close to the target spatially, or visual masks. Effects of a prime depend on the prime's duration. In a forced-choice target identification task, brief primes produce a strong preference to choose the primed alternative, whereas long primes have the oppose effect. This interaction is well explained by a model that assumes the offsetting mechanisms of source confusion (prime features are confused with target features) and discounting (evidence regarding the prime features is discounted). Short primes produce under-discounting of prime features, whereas long primes lead to over-discounting. In the present study, the typical short-term priming experiment was augmented to include distractor words that appeared simultaneously with the target, flanking it on both the top and bottom. Flanker word duration was manipulated by allowing long flankers to remain after the target was masked. The experiment reproduced the established duration-dependent priming effects while observing novel effects of flanker duration. Whereas increasing the length of exposure to prime features leads to over-discounting, varying the flanker duration only led to differential levels of under-discounting with longer flankers being discounted more optimally. A computational model that includes both source confusion and discounting provides an excellent account of the effects of both the primes and the flankers.

(60)
Saturday, 4:10
Distler

Testing saccadic reaction times to

visual-auditory stimuli for oscillatory phase resetting. Adele Diederich, *Jacobs University, Bremen*, Hans Colonius, *Oldenburg University*. There is growing support of the hypothesis that coherence of oscillatory responses at the level of primary sensory cortices may play a crucial role in multisensory processing (Senkowski et al. TINS 2008; Schroeder et al. TICS 2008). According to the hypothesis, if two stimuli occur with a certain time lag, the first stimulus can reset an oscillation to its ideal phase; after reset, inputs that arrive within the ideal (high-excitability) phase, even within another modality, evoke amplified responses, whereas the responses to inputs that arrive slightly later during the worst phase are suppressed. Here we probe whether this putative mechanism leaves its marks in the pattern of saccadic reaction times to visual-auditory stimulus pairs in a focused attention paradigm. An auditory nontarget stimulus was presented via loudspeaker 20 degrees left or right from fixation, followed by a visual target (LED) presented either ipsi- or contralateral to the nontarget. Interstimulus intervals (ISI) ranged from zero to 202 ms in increments of 2 ms resulting in about 10 000 responses per subject (48 data points/ISI). Response facilitation, relative to the unimodal visual condition, of up to 70 ms was observed for the ipsilateral presentations. Spectral analysis suggests the existence of multiple temporal windows of high and low excitability.

(34)
Monday, 9:40
Distler

The structure of short-term memory scanning: An investigation using response time models. Chris Donkin, *Indiana University*, Robert Nosofsky, *Indiana University*. The way in which information is retrieved from short-term memory has a long history of investigation. There is, however, still no consensus on whether items in short-term memory store are accessed serially, or in parallel, or whether global access to the entire memory store is utilized to make recognition judgements. In the current investigation, we compare models of choice response times arranged into various architectures (serial exhaustive, parallel self-terminating, and global access) on their ability to account for choice and response time distribution data. We find that, despite providing an intuitive explanation for various qualitative patterns in mean response times, the serial exhaustive model struggles to account for the shape of response time distributions. Versions of both the parallel and global access models appear to provide viable accounts of the data.

(13)
Sunday, 3:30
Cohen

Type 1 and Type 2 models of the mirror effect in recognition memory. John Dunn, *University of Adelaide*, Lawrence DeCarlo, *Columbia University*. The mirror effect in recognition memory occurs when hit rates (HR) and false alarm rates (FAR) for strong (s) and 'weak' (w) items are ordered as follows: FAR(s) > FAR(w) > HR(w) > HR(s), and can be modeled within a signal detection framework in two ways. Type 1 models place strong and weak items on separate evidence scales and allow different sets of de-

cision criteria on these scales. The unconstrained Type 1 model is not identifiable so most interest is in constrained versions which propose a relationship between the two sets of decision criteria. Type 2 models place strong and weak items on a common strength of evidence scale and assume a common set of decision criteria. Recently, Glanzer, Hilford and Maloney (2009) proposed a likelihood ratio based model which they argued accounted for the mirror effect as well as two other effects found in the literature. We show that this is an example of a constrained Type 1 model and compare it to another constrained Type 1 model in which the decision criteria are linear functions of each other; this model is formally identical to an unequal variance Type 2 model. We show that both models account for the three regularities identified by Glanzer et al. and compare their fit to extant data sets using AIC and BIC. We conclude that the linear Type 1 model is simpler and fits the data better than alternative Type 1 models. The results support the view that participants do not systematically shift their decision criteria between strong and weak items.

(74)
Saturday, 3:10
Distler

Testing Theories of post-error slowing. Gilles Dutilh, *University of Amsterdam*, Joachim Vandekerckhove, *University of Leuven*, Birte Forstmann, *University of Amsterdam*, Eric-Jan Wagenmakers, *University of Amsterdam*. People tend to slow down after they make an error. This phenomenon, generally referred to as post-error slowing, has been hypothesized to reflect perceptual distraction, time wasted on irrelevant processes, a priori bias against the response made in error, increased variability in a priori bias, or an increase in response caution. Although the response caution interpretation has dominated the empirical literature, little research has attempted to test this interpretation in the context of a formal process model. In this study, we used the drift diffusion model to isolate and identify the psychological processes responsible for post-error slowing. In a lexical decision data set comprised of 1,094,886 responses we found that post-error slowing was associated with an increase in response caution and 'to a lesser extent' a change in response bias. In the present data set, we found no evidence that post-error slowing is caused by perceptual distraction or time wasted on irrelevant processes. These results support a response monitoring account of post-error slowing.

(72)
Saturday, 11:45
Alumni

Information structure and the acquisition of numerical understanding. Michael Ramscar, *Stanford University*, Melody Dye, *Stanford University*, Hanna Popick, *Stanford University*, Fiona O'Donnell-McCarthy, *Stanford University*. Although number words are common in everyday speech, for most children, learning these words is an arduous, drawn out process. Here we present a formal, computational analysis of number learning that suggests that the unhelpful structure of the linguistic input may be a large contributor to this delay, and that manipulating this structure should greatly facilitate learning. We conducted three

simulations with an error-driven model of learning. The first simulated the effects of prenominal and postnominal presentation on number learning; the second examined the effects that the peculiar information structure of number sets has on number learning; and the third integrated these factors, to examine predicted learning outcomes. These simulations indicate: 1) that as set size increases, the problem of discrimination gets successively harder, requiring increasing amounts of information, just as the information available to the learner is shrinking; 2) that once the environment and the representational requirements of sets are taken into consideration, a continuous system for learning, representing and discriminating set-sizes can give rise to effective discontinuities in processing; and 3) that postnominal training can successfully facilitate discrimination learning, whereas typical prenominal training cannot. A training-experiment with three-year olds confirms these predictions, demonstrating that significant gains in numerical competence are possible given appropriately structured training. At the same time, the experiment illustrates how little benefit children derive from the usual training that parents and educators provide. We discuss these findings in view of the large body of research showing how strongly early numerical ability predicts later educational outcomes.

(29)
Sunday, 10:45
Distler

Joint Distribution Criterion and Linear Feasibility Test for Selective Influences. Ehtibar Dzhafarov, *Purdue University*, Janne V. Kujala, *Jyvaskyla University*. The problem of selective influences has applications ranging from modeling pairwise comparisons to reconstructing mental processing architectures to conjoint testing. A necessary and sufficient condition for a given pattern of selective influences is provided by the Joint Distribution Criterion, which reduces the problem of 'what influences what' to that of the existence of a joint distribution for a certain set of random variables. For inputs (external factors) and outputs (random variables) with finite or finitely discretized sets of values this criterion translates into a test of consistency of a certain system of linear equations and inequalities (Linear Feasibility Test) which can be performed by means of linear programming.

(80)
Monday, 10:00
Distler

Voluntary Control Over The Temporal Distribution Of Attention In Scanning Short Term Memory. Mario Fific, *Max Planck Institute*. We propose the existence of an attention gating mechanism that scans items in short-term memory in a way similar to the scanning of information outside the cognitive system during visual object recognition. We test this in an experiment in which subjects determine whether a target item is a member of a sequentially presented list of items. We manipulate subjects' temporal distribution of attention across items in the list in three conditions: subjects respond very quickly if the target appears in (1) the first half, (2) the second half, or (3) any part of the list. Results support the idea that the scanning of items in short-term memory is guided

by voluntary control over the distribution of strictly limited attentional resources across time. The effects of set size, capacity limitation, and serial position are captured by the Exemplar-Based Random Walk model, which relates retrieval speed and accuracy to attention gating.

(33)

Monday, 9:20

East Sophia Gordon Bldg.

Letter position representation in reading: An axiomatic analysis of the transposition priming effect. Simon Fischer-Baum, *University of Illinois, Urbana-Champaign*, Paul Smolensky, *Johns Hopkins University*. In the past decade, a range of empirical results has challenged classical models of visual word recognition. For example, slot-filler theories (e.g. Rumelhart & McClelland, 1981) cannot explain transposition priming (Perea & Lupker, 2003) whereby a target word (HORSE) is primed more by a non-word with two transposed letters (hosre) than one in with substituted letters (hople). Recent computational theories of visual word recognition can explain transposition priming (e.g., Davis, 2010; Gomez, Perea & Ratcliff, 2008; Grainger et al., 2006; Hannagan, Dupoux & Cristophe, 2011), though, on the surface, these proposals differ in the mechanisms they use to account for the result (e.g., spatial coding, perceptual uncertainty, open bigrams, holographic reduced representations). We present an axiomatic analysis of visual word recognition and transposition priming that answers the following question: Which properties of theories of visual word recognition deserves credit for correctly predicting transposition priming or blame for failing to do so? The results are clear; theories that are able to account for transposition priming use positive-overlapping letter position representations and theories that cannot use orthogonal position representations. Indeed, we present theorems that prove, given general and commonly-held assumptions about visual word processing, that positive-overlapping position representation is a sufficient condition for predicting transposition priming and non-orthogonal position representation is a necessary condition. In light of these results, we discuss the benefits of an axiomatic approach to linking experimental results to cognitive theory.

(73)

Sunday, 9:00

Alumni

Separate Bayesian inference reveals model properties shared between multiple experimental conditions. Ingo Freund, *TU-Berlin and BCCN*, N. Valentin Haenel, *TU-Berlin and BCCN*, Felix A. Wichmann, *TU-Berlin and BCCN*. Statistical modeling produces compressed and often more meaningful descriptions of experimental data. Many experimental manipulations target selected parameters of a model, and to interpret these parameters other model components need to remain constant. For example, perceptual psychologists are interested in the perception of luminance patterns depending on their contrast. The model describing this data has two critical parameters: the contrast that elicits a predefined performance, the threshold, and the rate of performance change with increases in

contrast, the slope. Typical experiments target threshold differences, assuming constant slope across conditions. This situation requires a balance between model complexity to perform joint inference of all conditions and the simplicity of isolated fits in order to apply robust standard procedures. We show how separate analysis of experimental conditions can be performed such that all conditions are implicitly taken into account. The procedure is mathematically equivalent to a single Gibbs sampling step in the joint model embracing all conditions. We present a very natural way to check whether separate treatment of each condition or a joint model is more appropriate. We illustrate the method for the specific case of psychometric functions; however the procedure applies to all models that encompass multiple experimental conditions. Furthermore, it is straight forward to extend the method to models that consist of multiple modules.

(54)
Saturday, 3:10
Cohen

Specification Testing using Eigenspectrum-Based Information Matrix Tests. RICHARD GOLDEN, *University Texas at Dallas*, STEVEN HENLEY, *Martingale Research Corporation*, HALBERT WHITE, *University of California,San Diego*, MICHAEL KASHNER, *Loma Linda VA Medical Center*. A 'specification test' is a statistical test that tests the null hypothesis that the researcher's probability model contains the data generating process. Although models that are correctly specified may often provide good fits to the data, the concept of goodness-of-fit (i.e., prediction error) is distinct from the concept of correct model specification. For example, small residual non-normal prediction errors in a linear regression model would indicate 'good fit' in the presence of model misspecification. One popular test for detecting model misspecification is the Pearson chi-square test that tests the null hypothesis that the probabilities predicted by a categorical model (e.g., a multinomial model or logistic regression model) can adequately represent the categorical frequencies of events in the environment. However, these types of tests are often plagued with the problem of excessive degrees of freedom. White (1982) proposed the concept of an Information Matrix Test (IMT) designed to detect the presence of model misspecification by testing that the null hypothesis the Hessian and OPG (Outer-Product-Gradient) asymptotic covariance matrices are identical. In this talk, we introduce a generalization of White's (1982) specification testing methodology by testing a null hypothesis that compares nonlinear functions of the asymptotic Hessian and OPG covariance matrices. We then introduce five new eigenspectrum-based Generalized Information Matrix Tests (GIMTs) (whose degrees of freedom are always bounded by the number of free parameters) and demonstrate these new GIMTs have very appealing level and power performance in an extensive series of simulation studies using a realistic epidemiological data analysis problem.

(38)
Monday, 3:10
Distler

Naming on a Directed Graph.

Giorgio Gosti, *University of California, Irvine*, William Batchelder, *University of California, Irvine*. We address how the structure of a social communication system affects language coordination. The naming game is an abstraction of lexical acquisition dynamics, in which N agents try to find an agreement on the names to give to objects. Most results on naming games are specific to certain communication network topologies. We first consider the simplest version of the naming game where there is a single object whose name is at stake, and agents are embedded in an arbitrary weakly connected digraph structure. We show that the resulting communication dynamics satisfy the properties of a Markov chain whose absorbing states correspond to a commonly accepted naming convention. Then we present necessary and sufficient conditions on the digraph structure that determine if the naming game will converge to a naming convention with probability one. The key is whether or not the digraph has at least one dominant node that has a directed path to all other nodes. In cases where convergence is not guaranteed, the communication system has a non-negligible probability of cycling through states where a collective naming agreement is never reached. We illustrate our results with some computer simulations. We then generalize our representation of the communication system to capture more cognitively realistic assumptions in the naming game. In particular, we endow agents with realistic memory assumptions and more reasonable selection rules. Also we allow speakers to communicate with multiple listeners, and objects to have possible structure.

(96)
Sunday, 4:30
Distler

Towards game theoretic analysis in large populations. Kshanti Greene, *Social Logic Institute*. We present an approach that enables one to analyze the decisions of a large population in a game theoretic manner. Graphical games reduce the complexity of finding Nash equilibria in N-Player games by having each individual act based on a small number of neighbors' strategies. However, there are many situations (such as in political decision-making) in which one is not interested in how one's neighbor acts, but in the portion of the population that takes on a particular action. Our approach enables one to find Nash equilibria in large populations by partitioning a population into collectives such that all members of a collective will take on a particular action given the distribution over actions of the rest of the population. The utilities or expected utilities of each member in a collective are then aggregated to form a *super agent* that represents the collective in a K-player game, where K is the number of collectives. K is derived from the number of action choices and will typically be much smaller than N in a large group. When K is small one can find Nash equilibria for the population efficiently even when the graphical game is fully connected. When K is larger, one can create a graphical game in which the K players are connected to a smaller number of neighbors. This work extends concepts presented at the 2010 MathPsych *Wisdom of the Crowd* workshop and moves towards a more formalized model for

game theoretical analysis in a large population.

(93)
Sunday, 4:10
Distler

Information Theoretical Approach to Statistical Network in Bodily Actions. Shohei Hidaka, *JAIST*, Chen Yu, *Indiana University*. Our bodily motion is coherent, smooth and effortless. Although most of us can easily read what others intend to do through their actions, there is a significant gap from a physical motion – a set of trajectories of multiple body parts with a large degree of freedom – to such high-order characterizations such as goals and intentions (Blake & Shiffrar, 2007). As the first step toward understanding high-level attributes in human actions, we propose a new analysis on behavioral time series which allows us to characterize informational dependency in fine-grained bodily motions. A set of human actions was collected in our experiment from relatively simple (e.g., waving a hand) to relatively complex (e.g., holding an object and moving it on the other place) measured by a full-body motion tracking system. In the analysis, we measured statistical dependency in a body-action space which was characterized as a multidimensional trajectory in a nonlinear dynamical system. The proposed generalized information-theoretic measure maps body actions onto an information network with each node corresponding to one joint angle. The present analysis offers two implications. First, our analysis on informational dependency among bodily motions could reconstruct the whole body physical connectivity. Second, our analysis found not only the physical proximity but also the functional proximity in actions (e.g. actions showing the same intention can be grouped together in a multidimensional space). Thus, we show that the information-theoretic measure combined with the nonlinear time series analysis may serve as a basic modeling tool for functional properties in human actions.

(53)
Monday, 4:10
Cohen

Planning and Information Search in Multi-Stage Risky Decision Making. Jared Hotaling, *Indiana University*, Richard Shiffrin, *Indiana University*, Jerome Busemeyer, *Indiana University*. Research into risky decision-making has traditionally presented individuals with choice alternatives that provide an immediate reward or punishment based on the outcome of a single random event. Decisions are typically made in isolation, independent from any previous or subsequent choices. This approach neglects the complexity of everyday decision-making, which often involves multiple interdependent choices and several uncertain events. We present recent work that extends the traditional risky decision making paradigm by incorporating some of the complexities of real world choices. Participants completed a series of multistage decision trials, represented as branching decision trees. At decision nodes, participants chose which path to take through the tree. At chance nodes, a random event determined the path. Crucially, participants had the option to use some of the points earned on previous trials to reduce their uncertainty by purchasing infor-

mation about chance nodes. We review data showing how individuals incorporate factors like risk, information search cost, and degree of uncertainty when forming plans for multistage decision scenarios. Our results show individual differences, with several distinct strategies emerging. A comparison of multiple competing models is used to elucidate the cognitive processes at work.

(32)
Saturday, 3:50
Cohen

A Statistical Test for the Capacity Coefficient. JOSEPH HOUPT, *Indiana University*, JAMES TOWNSEND, *Indiana University*. The workload capacity coefficient is a measure of a participants' performance in redundant target trials relative to their estimated performance if they processed the signals in an unlimited capacity, parallel and independent (UCIP) manner. Among other attributes, one can assess the degree to which a participant performs better, or worse, than what would be expected from statistical facilitation alone. In this paper, we demonstrate the statistical properties of an estimator of UCIP performance, based on participants' response times on single target trials. We then present a null hypothesis significance test for comparing true performance in the redundant target trials to estimated UCIP performance.

(104)
Monday, 3:30
East Sophia Gordon Bldg.

An Associative Model of Inference in Statistical Word Learning. GEORGE KACHERGIS, *Indiana University*, CHEN YU, *Indiana University*, RICHARD SHIFFRIN, *Indiana University*. In the cross-situational statistical learning paradigm (Yu & Smith, 2007), participants learn word-referent pairings from a series of trials, each of which contains multiple words and referents. Thus, on any given trial the meanings are ambiguous, and to disambiguate the intended pairings learners must integrate word-referent co-occurrences across trials. Cross-situational studies show that adults can acquire a large number of pairings from only a few minutes of training, and that such learning can be modulated in unexpected ways by factors such as pair frequency and contextual diversity (Kachergis et al. 2010). The associative model we propose to account for these data incorporates competing biases for strengthening already-strong associations, and for giving more attention to stimuli with no strong associates (i.e., high uncertainty or entropy). With the simple assumptions that learners know the current strength of their associations, and that learners are aware of how uncertain their knowledge is about each stimulus, the model produces mutual exclusivity, inference, and trial order effects that closely match human data in a variety of experiments. Furthermore, we discuss how this model predicts recent active cross-situational learning data we have collected, in which learners choose which objects they will see on the next trial. Finally, we suggest that cross-situational word learning can usefully be thought of as a associative learning with multiple outcomes on each trial, and we link the mutual exclusivity bias to the blocking effect.

(75)
Sunday, 3:10

Cohen

Beyond ROCs: Fitting and extending recognition memory models with multiple-alternative, multiple-response tasks. David Kellen, *University of Freiburg*, Christoph Klauer, *University of Freiburg*, Henrik Singmann, *University of Freiburg*. Traditionally, recognition memory models are assessed by means of their predicted Receiver Operating Characteristic (ROC) functions. An often overlooked alternative for model fitting is the 4-alternative forced choice with 2 responses (4AFC-2R) task, originally used to test SDT assumptions (Swets, Tanner, & Birdsall, 1961). An important feature of the 4AFC-2R task is that no response criteria are postulated, criteria which so far have been ubiquitous. Despite this major difference, model predictions for 4AFC-2R and ROC tasks are closely tied, with their relationship being explicitly described by the Generalized Area Theorem (Iverson & Bamber, 1998). The main recognition memory models are specified in the context of the 4AFC-2R task and fitted to 4 datasets previously reported by Parks and Yonelinas (2009). Model fits were evaluated in terms of their corresponding Normalized Maximum Likelihoods and parameter estimates. Additionally, given the absence of response criteria in the 4AFC-2R task, this task can be complemented with ROC data in order to provide an assessment of response criteria variability (AKA: criterion noise) without the need for additional assumptions/restrictions, which represents an advantage when compared with previous approaches (e.g., Benjamin, Diaz, & Wee, 2009; Mueller & Weidemann, 2008). Data from two new experiments and corresponding model fits are reported.

(138)

Monday, 3:50

Cohen

A self-regulating accumulator model of cue search. Michael Lee, *University of California, Irvine*, Ben Newell, *University of New South Wales*, Joachim Vandekerckhove, *University of Leuven*, Shunan Zhang, *UC Irvine*. We apply a version of Vickers' self-regulating accumulator (SRA) model to the problem of choosing between two objects described by sets of features. Unlike most sequential sampling models, the SRA has a theory of adaptation. It has a theoretically elegant and psychologically plausible account of how the level of evidence needed to make decisions is set, and how it changes with task demands and environmental changes. We evaluate the model on experimental data in which people search cues to choose between pairs of objects, but the number of cues needed to make good decisions changes unexpectedly over blocks of trials. We contrast the good account SRA gives of the data (at the level of individuals, since there are large individual differences in search behavior) with alternative models based on standard reinforcement learning mechanisms.

(127)

Sunday, 9:40

Distler

Figure-ground organization from a single stereo image pair. Yunfeng Li, *Purdue University*, Longin Latecki, *Temple University*, Zygmunt Pizlo, *Purdue University*. In this study, we describe a new method to recover the layout of ob-

jects in a 3D scene from a single stereo image pair. Our method can (1) determine the number of foreground objects in the 3D scene, (2) estimate their 3D positions and orientations and (3) find the corresponding 2D regions in the image. The method consists of five steps: (1) Computation of depth map. We use the Sum of Absolute Difference Correlation Method to solve the stereo correspondence problem. Then we apply a triangulation method to recover the 3D points. (2) Estimation of the camera extrinsic parameters. This is equivalent to the computation of the camera's orientation relative to the ground floor. The ground floor was identified as the locally largest plane containing the largest number of points. (3) Computation of the top view image. After removing the points lying on the floor, we orthographically project the remaining 3D points on the floor to obtain the top view image. (4) Detection of objects. By fitting rectangles in the top view image, we detect the individual objects in a 3D scene, including their sizes and orientations. (5) Computation of the 2D regions in the image representing individual objects. These regions are projections of the 3D points representing individual objects in the depth map. Our method was tested with cluttered scenes containing multiple objects producing severe occlusions. The method solves the figure-ground organization accurately.

(103)
Monday, 3:10
East Sophia Gordon Bldg.

Feature Selection as Bayesian Model Comparison. Bradley Love, *The University of Texas*, Marc Tomlinson, *The University of Texas*. One learning challenge humans and machines face is learning which features are relevant predictors. Human experts may perform better in many domains because they have identified a rich vocabulary of relevant features. While not considering relevant features is clearly detrimental, including irrelevant features also decreases performance. Determining which features are relevant from a potential pool of thousands of features is a difficult challenge. We suggest that the feature selection problem is best poised as a Bayesian model selection problem. In our approach, competing models are formulated that involve different subsets of features and the likelihood these models given observed data is computed to determine which features are relevant. Standard measures, such as Bayes factors, are used to order possible models (i.e., feature sets). We evaluate how effective this approach is in identifying the features expert human gamers entertain while playing the real-time strategy game Starcraft. In the first study, we hand-constructed a set of plausible features and evaluated the ability of various approaches to discriminate these features from randomly generated features. The Bayesian approach with an informed prior performed best, followed by a Bayesian approach with an uninformed prior, followed by a closely related maximum likelihood technique commonly used in machine learning (i.e., the G-test). In a second study, the Bayesian approach with informed prior was used to analyze individual games to determine how feature use generalizes across game scenarios and experts. An individual's feature use was stable across games and there was significant, albeit lower, agreement across game maps

and individuals.

(39)
Saturday, 11:45
Distler

The Discriminability of Delay Discounting Models. Christian Luhmann, *Stony Brook University*. Normative economic theory suggests that the subjective value of delayed rewards should be an exponential function of delay. This is because exponential discounting prevents decision-makers from exhibiting contradictory preferences (e.g., abandoned New Year's resolutions). In contrast, the large majority of empirical data instead suggests that decision-makers' discount functions are hyperbolic in nature, which necessarily implies that they will exhibit irrational reversals of preference. Recent theoretical work has attempted to reconcile these accounts by noting that a decision-maker discounting exponentially over a nonlinear representation of time (e.g., Weber's law) will be indistinguishable from one discounting hyperbolically over a more veridical representation of time. However, proponents of hyperbolic discounting have recently demonstrated that behavior may be better described by incorporating nonlinear temporal representations into hyperbolic discounting itself. Thus, parsimony is no longer a useful guide for selecting between these competing models. To clarify the situation, I first employ a parametric bootstrapping cross-validation procedure to evaluate the degree to which exponential and hyperbolic models are able to mimic one another once nonlinear temporal representations are admitted. Results suggest that the two models are indistinguishable. I then exhaustively explore the full parameter space, only to reach similar conclusions. I then present new behavioral data that both sheds new light on previous empirical work and helps to eliminate much of the ambiguity revealed in the preceding analyses. Ultimately, I conclude, contrary to current thinking in the literature, that decision-makers are most appropriately conceptualized of as normative, exponential discounters that represent time nonlinearly.

(99)
Monday, 11:05
Distler

Intracranial recordings yield novel insights into how episodic memories are represented, stored, and retrieved. Jeremy Manning, *University of Pennsylvania*, Michael Kahana, *University of Pennsylvania*. We present two analyses of electrocorticographic recordings taken as human neurosurgical patients studied and freely recalled lists of words. In the first analysis, we identify components of neural activity that represent the meanings of the studied words. We find that individual differences in these neural patterns provides information about the order in which the patients will recall the words – a measure of how the words are organized in memory. In the second analysis, we identify a gradually evolving neural signal that appears to represent the temporal contexts in which each word is studied. As predicted by context-based models of episodic memory, the neural recordings show that this temporal context representation is reinstated just prior to recall. Individual differences in this neural signature of context reinstatement also pro-

vide information about the order in which participants will recall the words. Taken together, our analyses yield novel insights into how our brains represent, store, and retrieve episodic memories.

(132)
Sunday, 3:30
Alumni

A Bayesian parametric approach for the estimation of stop-signal reaction time distributions. Dora Matzke, *University of Amsterdam*, Conor Dolan, *University of Amsterdam*, Gordon Logan, *Vanderbilt University*, Scott Brown, *University of Newcastle, Australia*, Eric-Jan Wagenmakers, *University of Amsterdam*. The cognitive concept of response inhibition can be measured using the so-called stop-signal paradigm. In this paradigm, participants perform a two-choice reaction time task where, on some of the trials, the primary task is 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). Based on the horse-race model (Logan & Cowan, 1984), several methods have been developed to estimate SSRTs. None of these approaches, however, allows for the reliable estimation of the entire distribution of SSRTs. Here we introduce a Bayesian parametric approach that addresses this limitation. Our method is based on the assumptions of the horse-race model and rests on the concept of censored distributions. The method assumes that SSRTs are ex-Gaussian distributed and uses Markov chain Monte Carlo sampling to obtain posterior distributions for the model parameters. The method can be applied to individual as well as hierarchical data structures. We present the results of a number of parameter recovery studies and apply our approach to published data from stop-signal experiments.

(12)
Sunday, 3:50
Distler

Effort dynamics in supervised work groups with envious subordinates. Arianna Dal Forno, *University of Torino*, Ugo Merlone, *University of Torino*. In the recent literature the dynamics of effort allocation in supervised work groups has been examined. In particular the consequences of the perception of inequity has been analyzed in terms of efficiency. In this paper we consider a model of supervised work group and introduce an incentive scheme in which subordinates are compensated according to their capacity and therefore their monetary compensation may be different. In the economic literature some authors model envy assuming that agents exhibit aversion towards disadvantageous inequity in monetary payoffs. As a consequence, the result of this incentive scheme is that the lower capacity subordinate may perceive envy towards the other subordinate. We analyze the effort allocation dynamics when the lower compensation subordinate alters his effort allocation as the result of envy. Our results show that, while on one side envy makes the dynamics less complex, on the other side it may decrease the allocation efficiency. Furthermore, when envy is excessive it may drive the efficiency to zero since the group production becomes null.

(124)
Saturday, 9:20
Alumni

Improving Between-Individual Wisdom using Within-Individual Crowds. Brent Miller, *University of California, Irvine*, Michael Lee, *University of California, Irvine*, Mark Steyvers, *University of California, Irvine*. When averaging estimates from individuals, the aggregate often comes closer to the true answer than any individual's guess. Vul and Pashler (2008) found that averaging a pair of responses from the same individual also reduced that individual's error. It has been suggested that both effects are due to individuals sampling internal probability distributions to generate estimates; aggregation has the effect of reducing sampling error. If so, can we use multiple samples from individuals to infer the uncertainty in their given estimates and improve aggregation? In this study, we examine this 'wisdom of crowds' effect for a series of ranking tasks, where the goal is to reconstruct, from memory, the order of time-based events or the magnitude of physical properties. Each task is performed twice, with an intervening distracter task. In addition, we also investigate previous data sets on probability and percentage judgments collected by Vul and Pashler (2008) and Ariely et al. (2000). In one aggregation approach, we combine the judgments across individuals by weighting each individual with the inverse of the distance between their first and second judgments. We also develop a Bayesian aggregation model that is designed to explain the underlying uncertainty of information within as well as between individuals. We show that both aggregation approaches improve on the performance of a between-subjects-only aggregation scheme. Individuals who give similar first and second judgments are associated with a smaller uncertainty of the underlying ground truth, and the distance between judgments can be used to effectively weight judgments across individuals.

(101)
Sunday, 3:30
Distler

The single-headed arrow of psychological time: The impossibility of linear autoregressive models of sequential effects. Fermin Moscoso del Prado Martin, *CNRS*. Despite the salient disagreements between researchers on the role and importance of temporal correlations in sequences of behavioral responses, most authors seem to agree in that these correlations arise from a linear autoregressive process. Linear models are implicit in Gilden et al. (1995)'s original finding of $1/f^{\alpha}$ noise in human responses, and in the debate on whether ARMA/fARIMA processes (Wagenmakers et al. 2004), or 'whitened fractional Brownian motions' (Thornton & Gilden, 2005) should be used to model sequential effects. In this study, I use the method of surrogate series (Schreiber & Schmitz, 2000; Theiler et al., 1992) to investigate if linear processes are plausible models of behavioral sequences. Processes that are linear, or that are just a simple transformation from a linear process, should be reversible (Diks et al., 1995): the statistical properties of the sequence should not differ from the statistical properties of

a sequence with the same elements in the exact reverse order. For a large range of reaction time sequences originating from different experiments, I investigated the reversibility of the sequences. For each behavioral sequence, I generated 100 surrogate series using the iterative Amplitude Adjusted Fourier Transform, and tested for reversibility. In the great majority of cases, I found that the sequences were significantly irreversible. Therefore, linear processes, or any simple transformation of such processes, are inadequate for the analysis of behavioral sequences. This implies the necessity of non-linear time series analysis for understanding the origins and implications of temporal correlations in human behavior.

(41)
Monday, 3:30
Distler

A Thurstonian Model with Order Effects and Ties. James Negen, *University of California, Irvine*, William Batchelder, *University of California, Irvine*. We present an extension of the Thurstonian Case III model to include order effects, e.g. a home court factor, and ties, e.g. draws or no choice. In most Thurstonian models, the order or spatial arrangement in which choice alternatives are provided is ignored. In our model we specify a parameter for order effects. This parameter is especially important in applications to two-person contests where there is often an advantage to the home court or moving first in a game. The traditional approach to ties in Thurstonian models specifies a single parameter $\tau > 0$, and a tie occurs if the momentary utility difference is in the interval $(-\tau, \tau)$. Our model allows individuals to have different tie propensities. When there are N choice alternatives, our data structure for a fully replicated round robin consists of $N(N-1)$ trinomials, one for every ordered pair of choice alternatives. We develop a fully Bayesian approach to model inference. It includes: (1) a specially designed MCMC sampler, (2) useful identification conditions and reparameterizations, (3) results on the effects of various priors, and (4) several approaches to model checking. We also provide an example application of the model to two data sets: chess data from 8 high-ranking players, and the 2009-2010 season of Major League Baseball's National League (by defining a tie as a game requiring extra innings).

(44)
Sunday, 11:05
Distler

Analytic Construct Validity: Toward further Integration of Quantitative Cognitive Science, and Individual-Difference Assessment Technology. Jim Neufeld, *University of Western Ontario*. An overriding principle governing evidence for a psychometric measure's 'construct validity' is that the measure acts in accordance with theory. This principle can be applied to the interpretation of selected parameters of stochastic mixture distributions. Here, it is instantiated in a model architecture, where the scale, or rate, parameter of a base distribution of cognitive-performance latencies (e.g., ordinary Erlang, general Erlang, Weibull, Compound Poisson; or some assembly thereof) is randomly mixed according to the gamma distribution. The mixture

may occur, for example, across performance trials, within an individual, or across individuals within a group. The shape parameter k of the gamma mixing distribution is deemed to convey task-wise performer competence ('processing resources'). Supportive of this interpretation is the observation that finite values of the nth-order moment of the resulting mixture-model distribution of latencies is finite if and only if $k > n$. Non-convergence, otherwise, is taken to imply the existence of a critical corpus of very long, or essentially incomplete trials, and therefore of a sub-threshold level of prevailing task-wise competence. Construct validity for the interpretation of k takes several forms, including co-extension of k's effects with those of shape parameters of related mixing distributions; k's interaction with base-distribution parameters that arguably should modulate it's threshold values; and selected Bayesian-architecture properties, in which k participates. The latter properties also convey additional linkages with multi-item, individual-difference assessment technology, through their parallels to test length, and number of parallel-form test administrations.

(139)
Monday, 4:30
Distler

Symbolic Simulation: a grounded mechanistic account for processing symbolic information. NADER NOORI, *USC/Computer Science Department*, LAURENT ITTI, *USC/Computer Science Department*. Cognition by means of abstract symbolic concepts in an algorithmic manner is one of the tenets of mathematical cognition. Identifying the relationship between this evolutionarily newly emerged symbolic machinery and rudimentary older modal systems has motivated numerous studies mostly focused on grounding representation of symbolic concepts (Barsalou 2008). However recent evidences emerging from neuroimaging and patient studies suggest that modal systems for visually guiding actions in space play a role in mental operations on symbolic information that is beyond representation of symbolic concepts (Koenigs M. et al 2009, Knops A. et al. 2009). Motivated by these findings we posit a grounded mechanistic model for algorithmic controlled information processing in human brain. We propose a critical role for a spatially organized short-term memory which is used for anchoring task relevant items into the space. These anchors are used for selective processing of the maintained information. Selective processing of information (such as deletion of item from memory) in turn is made possible through shifts in spatial attention towards registry location of the item of interest in the space. This registry system along with an articulatory system for hashing items into phonological codes, and a system for performing and monitoring sequential actions provide necessary mechanisms for employing overly-trained networks for processing limited set of activated items in arbitrary algorithms. We have evaluated our hypothesis by detecting process related traces of mental symbolic operations in both eye movements of human subjects and visuospatial short-term memory of objects in the environment.

(18)
Sunday, 11:45
Alumni

Categorization-Based and Recognition-Based Memory Scanning. Robert Nosofsky, *Indiana University*, Stephen Denton, *Indiana University*, Chris Donkin, *Indiana University*. According to the exemplar-based random-walk model of memory scanning (Nosofsky, Little, Donkin, & Fific, 2011), despite involving different task goals, categorization and recognition decision-making reflect the same psychological processes. The same model should account simultaneously for categorization-based and recognition-based memory scanning, while making allowance only for adaptive changes in parameter settings across the tasks. For example, people should adopt a stricter criterion setting for accepting a test item as 'old' than for endorsing it as a member of a category. In our experiments, subjects are presented with memory sets composed of statistical distortions of a prototype pattern that defines a category. At test, they are probed with either old members of the category, new statistical distortions of the prototype, or random patterns that are unrelated to the category. The goal is to predict categorization and recognition choice probabilities and response times as a function of variables such as the size of the memory set, the type of test probe, and the lag with which positive probes were presented. The theoretical goal is to develop a unified formal account of multidimensional perceptual categorization and recognition and memory scanning.

(140)
Saturday, 12:05
Alumni

Simulating Word Learning for Continuous Stimuli via Prediction-Error. Adam November, *Stanford University*, Michael Ramscar, *Stanford University*. The world is full of perceptually similar stimuli that require behaviorally diverse responses. Picking ripe fruit, avoiding poisonous creatures, and even interpreting subtle facial expressions all rely upon learned discriminations of subtle cues. Recent work (Ramscar, Yarlett, Dye, Kenny, & Thorpe, 2010) applied an error-driven model to leaning mappings between discrete-featured stimuli and respective labels, uncovering asymmetries in learning depending on the temporal structure of the pairings during training (known as Feature-Label-Order effects). Here, we extend the model to learn continuous (rather than discrete) stimuli. By exploring the interactions of temporal order, item frequency, and item discriminability, we provide clear evidence for a prediction-error-driven mechanism in learning mappings between labels and continuous object features. We show that informative but low-frequency cues are relatively well-learned when they are used to predict labels during training, but are relatively poorly-learned when the labels are used to predict the features during training. We confirm this prediction in a series of human experiments using novel 2-d shapes, and discuss the results in the larger context of symbolic learning. Further simulations explore the effects of initial representational sparseness on subsequent learning. While learning to use features to predict labels is robust across broad levels of sparse or redundant coding, predicting in the other direction can be easily disrupted by codings outside of a narrow effective range. We discuss these simula-

tion in the context of differences in symbolic learning in various sensory modalities, e.g. learning to name pitches vs colors.

(115)
Monday, 10:45
East Sophia Gordon Bldg.

What are the boundary conditions of differentiation? A test of the context shift hypothesis. Adam Osth, *The Ohio-State University*, Simon Dennis, *The Ohio-State University*. One of the critical findings in recognition memory is the null list-strength effect (LSE), which states that strengthening items by extra study time or extra repetitions does not hurt the performance of other studied items. Episodic memory models were able to predict the null LSE by using the principle of differentiation, which states that repetitions of a single item accumulate into a single strong memory trace. A hypothesized boundary of the differentiation process is that repetitions of a single item in different contexts will create new traces. Three experiments were conducted that tested this hypothesis by repeating words across different study-test cycles rather than within a single study-test cycle and subsequently testing all the lists with an inclusion instruction. Results indicated that as the proportion of strong items increased, there was both a null LSE and a non-significant decrease in the FAR, which is contrary to the predicted strength-based mirror effect. These two results in tandem provide a challenge for differentiation models. These results were fit with the BCDMEM (Dennis & Humphreys, 2001) model with a modification to allow for noisy contextual reinstatement as well as the REM.4 model (Shiffrin & Steyvers, 1997), which contains a specified differentiation mechanism.

(94)
Saturday, 3:30
Distler

Revisiting visual-auditory integration in a redundant signal detection task. Jo Pan, *National Cheng Kung University*, Yi-Cheng Tsai, *National Cheng Kung University*, Cheng-Ta Yang, *National Cheng Kung University*. It has been found that detecting the presence of the multiple signals from both visual and auditory channels (multiple targets) is faster than detecting that from one of the channels (single target). This redundant target effect may have occurred due to visual-auditory integration. The visual-auditory integration suggests that participants adopt coactive processing to detect both types of signals and this has been verified by a violation of the Miller inequality (MI). However, according to the systems factorial technology (SFT), a violation of the MI does not necessarily mean coactive processing; it only suggests supercapacity processing. The process architecture and the stopping rule are inferred by using interaction contrast of mean reaction time and interaction contrast of survivor function in the multiple-target conditions. This study followed the SFT to design the experiment, analyze data, and infer the process characteristics when detecting visual and auditory signals. Three participants were required to detect the presence of visual, auditory, or both visual and auditory signal. Two levels of ambiguity of visual and auditory signals were manipulated. Results showed that all participants adopted parallel processing and followed a

self-terminating rule to detect the signals. Inconsistent with the prediction of coactivation model, these suggested that two signals are processed in parallel and each channel provides separate activation that race for a decision. The faster processing determines the decision. The inconsistency between the current and Miller's studies may have also resulted from the differences in the experimental context. Theoretical implications on the multi-sensory processing will be discussed.

(19)
Sunday, 9:20
Distler

A Test of Tri-Areal Matching Regularity for Two-Dimensional Stimuli. Lacey Perry, *Purdue University*, Ehtibar Dzhafarov, *Purdue University*. The notion of a regular well-matched space of stimuli was introduced in Dzhafarov & Dzhafarov (2010, Theoria, 76, 25-53) as a generalization of the Regular Mediality/Minimality and Matching Regularity principles to multiple observation areas. A central property of a regular well-matched stimulus space is that in any vector of stimuli in which each stimulus is matched by the next one, any two stimuli match each other (preventing thereby the comparative version of the ancient 'sorites paradox'). We investigated the hypothesis that two-dimensional dot locations comply with regular well-matchedness using three dots within three adjacent circles whose centers formed a triangle. The repeated consecutive matching procedure used was a tri-areal extension of the 'ping-pong' matching procedure used in Dzhafarov & Perry (2010, Frontiers in Quantitative Psychology and Measurement, doi:10.3389/fpsyg.2010.00024). The results, analyzed in terms of the first-order and higher-order differences in the coordinates of dots within each circle, are consistent with the regular well-matchedness hypothesis.

(52)
Sunday, 3:50
Alumni

A novel method for the analysis of sequential eye movements. Alexander Petrov, *The Ohio State University*, Taylor Hayes, *The Ohio State University*, Per Sederberg, *The Ohio State University*. Eye-movement protocols are an important data source in psychology, having improved our understanding in a wide range of areas. Yet despite this success, the vast majority of eye-movement studies ignore all sequential information in the data and utilize only first-order statistics such as fixation probabilities and dwell times. Here we present a novel application of a temporal-difference learning algorithm to construct a successor representation (SR, Dayan, 1993) that captures the statistical regularities in temporally extended fixation sequences. The result is a matrix representation that integrates over multiple time steps to estimate the expected discounted number of future fixations at location j given a current fixation at location i. We demonstrate the effectiveness of the SR method on eye movement data from 35 participants that solved 28 visual analogy problems from Raven's Advanced Progressive Matrices (APM) test. We performed a principal component analysis on the trial-averaged SRs for each individual participant and used the components to predict the in-

dividual APM scores. The two components with the highest regression weights had a clear and intuitive interpretation: one captured the systematicity of scanning patterns and the other quantified the tendency to toggle to and from the response area. This supports the theory that high-scoring individuals use a constructive matching strategy and low-scoring individuals use a response elimination strategy. Leave-one-out cross validation indicated that these two components predicted 41% of the variance in Raven scores. The SR technique thus shows great promise for analyzing the sequential properties of eye movements.

(68)
Sunday, 9:00
Distler

A necessary and sufficient condition for a 2D image to have a perceptually plausible 3D symmetric interpretation. Tadamasa Sawada, *Purdue University*, Yunfeng Li, *Purdue University*, Zygmunt Pizlo, *Purdue University*, Donald Bamber, *University of California, Irvine*. Our everyday life experience suggests that we can easily tell the difference between 3D symmetrical and asymmetrical shapes. Computationally, discriminating between 3D symmetrical and asymmetrical shapes from a single 2D retinal image is a difficult problem because the 2D retinal image of a 3D shape is almost always asymmetrical regardless whether the 3D shape is or is not symmetrical. One possible method to perform this discrimination is to verify whether a given 2D retinal image is geometrically consistent with a 3D symmetrical interpretation. Unfortunately, this method will not work because 3D symmetrical interpretations are almost always possible. Sawada, Li and Pizlo (2010) showed that, given two arbitrary curves in a single 2D image, one can always find a 3D mirror-symmetric interpretation under quite general assumptions. However, the symmetric interpretation derived from arbitrary curves often corresponds to a degenerate view. Specifically, substantial proportion of the 3D curves is hidden in depth. One way to avoid such degenerate 3D interpretations is to impose a planarity constraint. If a 3D curve is planar, the degenerate view happens only when the curve projects to a straight line segment in the 2D image. Such cases are easy to detect and eliminate. In this study, we derive the necessary and sufficient condition for a pair of 2D contours to have a 3D symmetric interpretation corresponding to a pair of planar curves under both perspective and orthographic projections.

(119)
Monday, 9:20
Distler

Modeling Multitrial Free Recall when Rehearsals are Covert. James Pooley, *University of California, Irvine*, Michael Lee, *University of California, Irvine*, William Shankle, *Medical Care Corporation*. Quantitative models of memory often assume latent rehearsal processes. Consequently, the application of memory models that assume such processes typically require the use of overt rehearsal data. However, these data are not always available in settings where the application of memory models has proven useful (e.g.,clinical assessments of memory performance). We show how hi-

erarchical Bayesian statistical methodology can be used to infer the latent patterns of rehearsals needed to successfully apply a quantitative model of memory to a clinical data set. We discuss the relevance of this research for clinicians interested in neuropsychological assessment as well as cognitive psychologists interested in basic memory research.

(14)
Monday, 10:00
East Sophia Gordon Bldg.

Coding Graphical Models: Probabilistic Context-Free Languages and the Minimum Description Length Principle. Brendan Purdy, *Moorpark College*. Graphical models are at the heart of cognitive modeling and there have been a number of approaches to model data as some sort of code. Solomonoff gave a probabilistic context-free language in order to model inductive inference. This model is similar to Russian's Minimum Description Length (MDL) Principle. While in essence both approaches view data as a string, the structure that the string takes is substantially different in each approach. In two recent papers, Wu, Myung, and Batchelder have used MDL to investigate a special subclass of graphical models, viz. Multinomial Processing Tree (MPT) models. Further, in a series of papers, Purdy and Batchelder have presented context-free languages for both Binary MPT models and the whole class of MPT models. Given that background, this paper has the subsequent topics. First, a topological compactness theorem is stated for Solomonoff's probabilistic context-free languages. Second, the MPT context-free language is viewed from the perspective of a probabilistic language. Next there is a comparison of results of the probabilistic MPT language with the MDL principle results from Wu, et al. Penultimately, a context-free language for a more general class of graphical models, i.e. Bayesian networks, is considered and this language is reformulated in a probabilistic fashion. Lastly, the probabilistic Bayes nets language is used as a method of inductive inference and its results are compared to those of the MDL principle.

(70)
Monday, 3:50
East Sophia Gordon Bldg.

Faster Teaching by POMDP Planning. Anna Rafferty, *University of California, Berkeley*, Emma Brunskill, *University of California, Berkeley*, Thomas Griffiths, *University of California, Berkeley*, Patrick Shafto, *University of Louisville*. To teach a learner, both human and computer tutors must monitor the learner's current knowledge and select pedagogical actions to lead the learner to the desired state of understanding. While there has been significant work in the cognitive science and education communities on monitoring and tracking the learner's knowledge, there has been less attention on how to automatically select teaching actions to achieve a learning goal and on how assumptions about the learner's knowledge impact the optimal teaching policy. In this work, we frame selecting teaching actions as a decision-theoretic problem and show how to formulate teaching as a partially observable Markov decision process (POMDP) planning problem. Given a learner model, this framework

allows us to select an optimal conditional teaching policy even given incomplete knowledge about the learner's understanding, and in contrast to approaches that only consider the immediate impact of the next action, POMDPs allow reasoning about both the immediate learning gain of a teaching action and its long-term benefit. We apply our formulation of teaching as POMDP planning to a simple concept-learning task and consider three distinct learner models for this task. We present approximate inference methods for handling the complexity of typical teaching domains, and show that teaching using POMDP planning results in accelerated learning in this task over baseline performance. While all three learner models result in some improvements in learning, the more complex models result in the most efficient learning, demonstrating the impact that assumptions in the learner model can have on problem selection.

(136)
Saturday, 3:50
Alumni

Capturing the battle between ideas and ambiguities: A computational study on the cognitive paradigm associated with the design thinking. Duwarahan Rajendra, *University of Pittsburgh*. Design thinking is a methodology for a practical, creative resolution of problems or issues that looks for an improved future result .So We understand how crucial it is to have ideas on our side to make design moves rapidly but in reality the ideas are surrounded by ambiguities and ambiguities are surrounded by ideas. They are indeed inseparable. The technique discussed here, is based on a new framework called Abacus-Linkography System (ALS) which is used to streamline the complicated thought process associated with the design thinking. The ALS work is similar to a chess board but instead of white & black pieces, now we have 'ideas' and 'ambiguities' at our disposal. When ideas are overwhelmed by ambiguities, we saw a pattern of fixation among designers. Likewise, when ideas overwhelm ambiguities the obtained pattern of fixations are interesting too. To get hold of these patterns, Shannon's entropy was used, i.e. 'idea' entropies and 'ambiguity' entropies are calculated. The tool described here was used to analyze the design cognition with a passive study (i.e. studying the documentation that was prepared during the design activity). It is encouraging as we get to have a close look at fixations, a recurring problem among designers. The future of this work is to see whether self awareness of fixations can be primed at all with the web bases services and mobile devices.

(71)
Saturday, 11:05
Alumni

The Evolution Of Noun Classification In Two Germanic Languages. Michael Ramscar, *Stanford University*, Richard Futrell, *Stanford University*, Melody Dye, *Stanford University*. For generations, linguists, philosophers and psychologists have accepted the idea that grammatical gender serves no functional purpose, even though it has co-evolved across many different languages. We question this 'purposeless' assumption by considering the case of the German gender system and examining whether gendered determiners might

play an informative role in language processing. An information theoretic analysis of German reveals that the gender system serves to make nouns more predictable in context. Moreover, like other subsystems of language - such as verb inflection - the gender system is more specifically informative about high frequency items than low frequency items. To further assess the functional role that gender plays, we then compare German to modern English, a Germanic language that has largely shed its gender system. We find that grammatical gender allows German speakers to use a wider variety of nouns after articles. However, it appears that English has systematically compensated for its diminished gender system by extending the use of prenominal adjectives, employing them with greater frequency as the frequency of the nouns they precede decreases. We show that not only do English prenominal adjectives help to make nouns more predictable in context, but that the distribution of prenominal adjectives is organized to optimize this function by ensuring that prenominal adjectives provide more support for low frequency nouns than high frequency nouns, thereby helping to make all nouns equally predictable in context. We consider the implications of these findings for our wider understanding of language and communication.

(48)
Saturday, 9:00
Distler

Rationality or Irrationality of Preferences? A Probabilistic Specification of Tversky's Lexicographic Semiorders. Michel Regenwetter, *University of Illinois, Urbana-Champaign*, Ying Guo, *University of Illinois at Urbana-Champai*. Amos Tversky's seminal paper on 'intransitive preferences' in Psychological Review (1969) has set the stage for a substantial multi-disciplinary literature that reports that individual human and animal decision makers can have intransitive, hence irrational, preferences. Tversky suggested that the participants in his experiments made choices among gambles in accordance with intransitive lexicographic semiorders. Regenwetter, Dana, and Davis-Stober have revisited this literature (Psychological Review, 2011; Frontiers in Quantitative Psychology and Measurement, 2010) and demonstrated an array of conceptual, mathematical, and statistical errors in prior work. They concluded, using both prior and new data, that observed choice behavior is consistent with variable, but transitive, latent preferences. This talk revisits Tversky's original idea and develops a new probabilistic model of lexicographic semiorders that permits rigorous quantitative testing of Tversky's idea. Full fledged testing of this model requires order-constrained statistical inference, which has only be developed in the last few years. We will introduce the model, discuss its mathematical properties, and illustrate its descriptive performance with some empirical data.

(128)
Sunday, 12:05
Alumni

A Model of Generalization and Feature Representation Across Graph Hierarchies. Timothy Rubin, *University of California, Irvine*, Matthew Zeigen-

FUSE, *Michigan State University*, MARK STEYVERS, *UC Irvine*. We present a novel modeling framework for representing category exemplars and features. In this approach, each exemplar is treated as a probability distribution over a hierarchically structured graph. The model jointly learns a feature representation for each node in the graph, as well as a distribution over these nodes for each exemplar. We demonstrate that this model is useful for learning feature representations for nodes in the graph that are not directly assigned any data (i.e. for generalization to new categories). Additionally, we illustrate that this model may be useful for understanding additional psychological aspects of concept representations, such as typicality ratings.

(90)
Sunday, 9:20
Alumni

Determining the Order of Mental Processes by Selectively Influencing Them. RICHARD SCHWEICKERT, *Purdue University*. One way to obtain information about the way processes are organized in cognitive tasks is by finding experimental factors that selectively influence the processes. If the processes are in a multinomial processing tree, the structure of the tree can sometimes be determined from accuracy data. Similarly, if the processes are in a directed acyclic task network, the structure of the network can sometimes be determined from reaction time data. In some cases the order of two sequential processes can be determined. An example is given for a multinomial processing tree model of immediate memory, and for a directed acyclic task network model of the psychological refractory period. Combining order information from several experiments with a comparability graph is discussed.

(123)
Monday, 12:05
Distler

A neural mechanism to represent the recent past. KARTHIK SHANKAR, *Syracuse University*, MARC HOWARD, *Syracuse University*. How is a stimulus experienced in the recent past and the subsequent passage of time represented in the brain? Temporal difference (TD) learning algorithm and related reinforcement learning models generally assume a complete serial-compound representation of the stimulus. The stimulus is thought to initiate a cascade of sequential activity so that a distinct neural unit is active at each moment following the stimulus. Here we propose a mechanism (TILT) to neurally realize such a stimulus representation over multiple time scales (sub-second to many minutes) relevant to cognition. We show that simple feed forward excitatory-inhibitory connections from a population leaky integrators can construct a serial-compound-like stimulus representation. The advantage of this mechanism is that the stimulus representation is automatically scale invariant such that the representation of a stimulus from distant past is fuzzier than the representation of a more recent stimulus. We propose that this fuzzy scale-invariant stimulus representation could underlie cognitive phenomena like timing behavior, episodic memory and reinforcement learning. This representation of stimulus history also provides a natural mechanism to generate predictions for the imminent future. More interestingly, by

simply rescaling the excitatory-inhibitory connections, the temporal representation of the stimulus history can be translated forward or backward along a mental time axis. This mechanism could potentially explain how we mentally fast-forward or rewind events, or search for an item from the recent past.

(126)
Saturday, 12:05
Distler

Assessing Consistency of Paired Comparisons in the Analytic Hierarchy Process. Jared Smith, Douglas Jessell. The Analytic Hierarchy Process (AHP) is a popular method for model assisted decision-making used across a wide range of domains. The original 1977 work by Thomas Saaty remains one of the most cited paper in the Journal of Mathematical Psychology with over 2,000 citations. A critical component of AHP is the conversion of pair-wise ratio comparisons into a meaningful subjective scale. Our present research examines AHP's method for deciding whether such a subjective scaling is possible given observed inconsistencies in an individual's responses. AHP assesses consistency through a comparison between observed and randomly generated responses. Observed responses are considered sufficiently consistent if they are more consistent than a large majority of random responses. However, as we demonstrate, this approach depends critically on the distribution used to draw the random responses. Through simulation and reference to existing literature we show that the distribution used in AHP is unreasonable given the types of errors that can be expected in actual responses. An alternative distribution is proposed in order to provide a more effective test of response consistency.

(100)
Monday, 11:05
East Sophia Gordon Bldg.

The Dimensionality of Contexts. Vishnu Sreekumar, *The Ohio State University*, Yuwen Zhuang, *The Ohio State University*, Simon Dennis, *The Ohio State University*, Mikhail Belkin, *The Ohio State University*. Episodic memory is a memory system that allows people to be consciously aware of a past experience in a certain situation at a certain time (Tulving, 1993). Mathematical models of memory commonly employ a context cue. Context plays a central role in context noise models like the BCDMEM (Dennis & Humphreys, 2001). The issue of what context is in the real world is yet to be addressed satisfactorily. If memory is dominated by context noise, it becomes useful to know what the similarity structure of real world contexts looks like. As a first step towards specifying what that is, a correlation dimension analysis is done on the space of visual contexts. We have subjects use a Microsoft Research SenseCam that captures images every 10 seconds for 5-7 hours every day for a week. A recently developed color correlogram representation is used to represent each image. A procedure similar to that employed by Latent Semantic Analysis is performed on the image by feature matrix and between-context image pair distances are calculated. The resulting correlation dimension plots show that visual contexts exhibit a two-scaled 'weave' structure with the dimension at short length scales

lower than the dimension at longer length scales, much like the structure of natural language discourse (Doxas, Dennis, & Oliver, 2010). While the correlation dimension characterizes the geometry of contexts, the embedding dimension allows us to draw direct conclusions about the dynamics of context change. To conclude, we will contrast the results from the two procedures.

(30)
Saturday, 9:40
Distler

Cognitively efficient need satisfaction: a novel intrinsic reward model explains multiple cognitive biases. Nisheeth Srivastava, *University of Minnesota*, Paul Schrater, *University of Minnesota*. The classical paradigm in choice-selection theories 'maximizing expected utility' has been shown by multiple studies to be predictively inaccurate and causally implausible. While incremental modifications to the standard model have shown some promise in predicting subjects' behavior in particular cognitive niches, such ad-hoc formulations are scientifically uninteresting. We have recently shown how alternative assumptions about the fundamental premises of decision theory can lead to a model of decision-making that is both neurobiologically and behaviorally realistic. We assume the value of possible outcomes is encoded relative to other available outcomes, not with respect to some fixed psychological 'no reward' condition. Further, we assume that evolutionary selection has predisposed organisms to minimize the costs of computing decisions while selecting between different actions. From these assumptions we retrieve a formal model of sequential decision-making that improves upon existing decision theory in interesting ways. We will describe results of computational experiments where our model generatively replicates multiple well-known cognitive biases, the prospect theory risk aversion patterns, confirmation biases, hyperbolic discounting and serial ordering effects. Applications in game-theoretic prisoners' dilemma settings yield results demonstrating a common basis for the emergence of learned altruism, follow-the-leader, and preferential attachment effects. The unforced emergence of such a wide variety of previously unconnected behavioral biases provides support for the causal validity of our assumptions and the resultant model. Our results provide striking evidence in favor of re-evaluating the traditional definition of rationality: from resource-constrained utility maximization to cognitively efficient need satisfaction, a conclusion with potentially deep implications across disciplines.

(78)
Saturday, 4:30
Alumni

Application of the Model of Hierarchical Complexity to the derivation of Wave Equations and String Theory. Kristian Stalne, *Lund University*, Michael Commons, *Harvard Medical School*. The derivation of the acoustic wave equation for a fluid in one dimension and its generalization to String Theory is presented as increasing Orders of Hierarchical Complexity from order 8 concrete up to 14 cross-paradigmatic. The derivation is performed by coordinating elements from the respective previous order. Ab-

stract variables of e.g. acoustic pressure, time and location are created by coordinating every possible concrete special case of the variables, respectively. Formal relations, e.g. pressure as a function of time, coordinate the two abstract variables pressure and time. At the systematic order pressure, particle velocity or density can be expressed as multivariate functions of both time and location. At the metasystematic order two of the three above mentioned functions are coordinated by means of the three metasystematic relationships of Newton's law of motion, the Constitutive equation and the Ideal gas law, respectively. These three relationships in turn are coordinated to form the wave equation, which is found at the paradigmatic order. The wave equation can be found in many shapes and in many other areas such as electromagnetics and the Schrödinger equation which is the foundation of quantum mechanics. At the paradigmatic order Einstein formulated the general theory of relativity. String theory is the result from the coordination of the two paradigms of quantum mechanics and the general theory of relativity at the cross-paradigmatic order. This result gives an understanding of how knowledge is organized. It also serves as an illustrative example of the principles of the Model of Hierarchical Complexity.

(95)
Sunday, 11:25
Distler

PSP based model selection. Sara Steegen, *University of Leuven, Belgium*, Francis Tuerlinckx, *University of Leuven*, Wolf Vanpaemel, *University of Leuven*. Parameter Space Partitioning (PSP; Pitt, Kim, Navarro, & Myung, 2006) is a recently developed method that partitions a model's parameter space into different regions that correspond to different qualitative data patterns. Every region is given a volume, reflecting how representative the corresponding pattern is for the model. PSP has been applied to gain insight in the global model behavior, but it can also be modified to serve as a formal model selection method. In particular, we propose a criterion to select between models based on the correspondence between a model's partitioned parameter space and an empirical data pattern by calculating the distance between the observed pattern and a model's data patterns, weighted by the corresponding volumes. Unlike most other model selection methods, which focus on quantitative data, this PSP based model selection method concentrates on the fit of qualitative patterns in the data. Using a model recovery study, focusing on category learning models, the PSP based model selection method will be evaluated and compared to existing model selection methods (Pitt, M. A., Kim, W., Navarro, D. J., & Myung, J., 2006).

(143)
Monday, 4:10
Distler

Dirichlet Process Mixture Models for Information Aggregation. Mark Steyvers, *University of California, Irvine*. In many probabilistic models for information aggregation, the assumption is that the collective wisdom of the group can be represented by a single latent representation (the 'latent truth'). In these models, each individual's estimate of

the truth is modeled as a sample from a distribution that is centered on the latent truth. Because of the assumption of a single underlying group belief, these aggregation models attempt to find consensus across all individuals in the group. In many cases however, it might be more accurate to assume that there are different subgroups in the population each with their own set of beliefs. This situation might arise when individuals use different processes to arrive at the answer or when the judgment is based on subjective preferences. Here, we adopt a non-parametric Bayesian approach to find the number of subgroups in a group as well as the parameters that describe the set of beliefs within each group. We apply a Dirichlet process mixture model (DPM) to a Thurstonian model for rank-order aggregation. We illustrate this model on rank-ordering tasks where individuals forecast the orderings of NBA teams and reconstruct, from memory, the order of time-based events or the magnitude of physical properties. We show that the DPM extension of Thurstone's model finds subgroups of individuals that produce consensus in different ways. For example, some subgroups appear to use decision heuristics in judging the strength of NBA teams and some subgroups appear to reach consensus because of in-depth knowledge of the NBA.

(58)
Sunday, 4:10
Cohen

An Intuitive Method that Explores Structural Properties of Multinomial Processing Tree (MPT) Models. Quan Tang, *The University of Memphis*, Xiangen Hu, *The University of Memphis*. Multinomial Processing Tree (MPT) models provide versatile and flexible methods for analyzing categorical data. Traditional hypothesis testing methods for MPT models are limited to test nested models, that is, the sub models within the same tree structure. There are cases where observations may support models with different tree structures. It is important to fully understand structural properties of a MPT model before conducting statistical analysis. In this paper, we propose an intuitive method for exploring the structural properties of MPT models. Specifically, our method builds a 'super tree' that contains all alternative MPT models. By adjusting the special parameters of this 'super tree', we can produce data sets based on each of the alternative MPT models and fit the data with different MPT models in the set of alternative MPT models. We implemented this method in GPT.EXE; however, the method can be implemented in other MPT software. In this paper, we will apply this method to two popular MPT models and discuss model selection issues on MPT models with different structures.

(15)
Saturday, 4:10
Cohen

Computerized Adaptive Testing and Adaptive Experimental Design. Yun Tang, *The Ohio State University*, Jay Myung, *The Ohio State University*, Michael Edwards, *The Ohio State University*, Mark Pitt, *The Ohio State University*. Computerized adaptive testing (CAT) has been intensively and widely studied in educational testing. In CAT, an

adaptive sequence of test items is chosen from an item bank so as to accurately infer the examinee's ability level with the fewest possible items. Recently in cognitive science, an experimental methodology dubbed adaptive experimental design (AED) has been developed under the Bayesian decision theoretic framework. The goal of AED is to conduct an experiment such that a participant's mental process can accurately be inferred in the fewest possible experimental trials. Given the similar goals and rationales the two adaptive methods, it would be useful to examine what each could learn from the other; especially what AED can learn from CAT given the latter's history of successful real world applications. Despite the recent demonstration of its feasibility, AED needs to overcome many challenges before being used routinely in cognitive experimentation. For instance, the huge computational cost of the AED algorithm hinders its application in real-time experiments. In contrast, CAT has various ready-to-use toolboxes for speeding up computation. We explored the possibility of multi-stage experimentation in AED, adopting the multi-stage testing method in CAT. The basic idea is that instead of trial-by-trial adaptation, experiment designs could be updated after a block of trials and the computation time between adaptations could be used flexibly to keep participants motivated. In this paper we present simulation results showing the advantages of the multi-stage setup in AED.

(105)
Sunday, 10:45
Alumni

Evolutionary models of color categorization on networks. Sean Tauber, *University of California, Irvine*, Louis Narens, *University of California, Irvine*, Kimberly Jameson, *University of California, Irvine*. The formation of color categorization systems using evolutionary simulation methods are investigated on various networks. Simulated agents have a minimal perceptual psychology of discrimination and simple learning and evolutionary mechanisms (e.g., reinforcement, imitation) are employed. Simple pragmatic constraints involving effective communication among agents are formulated and applied. It is found that individual learning, group consensus, the structure of individual and group categorization, as well as measures of optimality vary with the kind of network under consideration.

(84)
Saturday, 11:05
Distler

Disentangling Models of Evidence Integration. Andrei Teodorescu, *Tel-Aviv University*, Marius Usher, *Tel-Aviv University*. Decision making has been studied using a variety of experimental paradigms. Here, we focus on dynamically changing noisy perceptual stimuli (which can also be thought of as a proxy for probabilistic evidence in higher, more general types of decisions)that require the accumulation of evidence over time. Such decisions have often and successfully been accounted for by models implementing a sequential sampling framework. However, a multitude of such models exist which, despite their profound structural differences are all able to fit existing empirical data

reasonably well. Quality of fit scores have been widely used to assess model capabilities and to compare different model architectures. We propose a different approach for comparing models which is based on isolating a specific model attribute and scrutinizing it to produce qualitative, rather than quantitative, predictions. Here, we choose the locus of competitive interactions (or lack thereof) as the focus of our investigation. By directly contrasting competitive mechanisms via computational simulations we produce qualitatively diverging predictions which we then test in the lab. In particular, we examine how different types of competitive (or non-competitive) models behave under independent manipulations of the amount of conflicting evidence (i.e., evidence supporting non-targets) and of prior probabilities. The simulations demonstrate that, with specific forms of conflicting evidence manipulations, independent and input-normalization models speed up while response competition models slow down. Our results provide strong support for the presence of high level 'response' competition and against independent and input competition models of decision making.

(66)
Monday, 9:00
Cohen

Modeling Response Times in the Go/No-Go Discrimination Task. Jennifer Trueblood, *Indiana University*, Michael Endres, *Indiana University*, Jerome Busemeyer, *Indiana University*, Peter Finn, *Indiana University*. We demonstrate how a formal cognitive model of response times can be used as a cognitive psychometric tool through an application to the Go/No-Go Discrimination (GNGD) task administered to subjects with varying degrees of substance use and antisocial behavioral disorders. The GNGD task is a reliable measure of passive avoidance (Newman et al., 1985), and it is considered an analog for real world approach-avoidance motivational conflict. Six motivationally distinct versions of the standard GNGD task were administered to examine the interactive effects of punishment type and reinforcement schedule. We modeled response times in this task using a Wiener process with a single absorbing boundary. The model parameters were fit to the individual data using hierarchical Bayesian parameter estimation in WinBUGS. Hyper parameters were associated with three diagnostic groups that differentiated subjects by their level of substance use and antisocial behavioral disorders. Estimates for the drift rate and boundary separation parameters were used to examine differences in cognitive functioning between diagnostic groups and experimental conditions. Using data from executive working memory tasks, we postulate that differences in cognitive functioning between groups, as seen by the model parameters, might be due to differences in working memory capacity. Ultimately, we show that formal cognitive modeling of response times has the potential to provide valuable insights into clinical phenomena that cannot be captured by traditional data analysis techniques.

(83)
Monday, 9:00
Distler

Bayesian Analysis of Memory Mod-

els. Brandon Turner, *The Ohio State University*, Simon Dennis, *The Ohio State University*, Trish Van Zandt, *The Ohio State University*. Many influential memory models are simulation based. This often leads to likelihood functions which are difficult or impossible to evaluate. We investigate the use of approximate Bayesian computation (ABC), which replaces the likelihood calculation with a simulation of the model. First, we investigated BCDMEM (Dennis & Humphreys, 2001), a contextual model of recognition memory which has analytical expressions for the likelihood (Myung, Montenegro, & Pitt, 2007). We performed a parameter recovery test using a standard Bayesian approach and the ABC approach, and concluded that ABC provides a legitimate approximation. Given these findings, we then used ABC to estimate the posterior distributions of the parameters in REM (Shiffrin & Steyvers, 1997), a feature-based simulation model. We then investigated model selection procedures between BCDMEM and REM. To do this, we developed a hierarchical mixture model, which we then fit using ABC. The mixture modeling approach provided insight to the relationships between the two models. This approach provided clear patterns in the ROC space where observed data would be more likely to have arisen from BCDMEM or REM, and unveils design-specific constraints on global memory models.

(79)
Sunday, 4:30
Alumni

Single-trial Parameters in the Linear Ballistic Accumulator. Leendert Van Maanen, *University of Amsterdam*, Scott Brown, *University of Newcastle*, Tom Eichele, *University of Bergen*, Eric-Jan Wagenmakers, *University of Amsterdam*, Birte Forstmann, *University of Amsterdam*. The Linear Ballistic Accumulator model (LBA) provides an elegant summary of behavioral data in N-alternative forced choice tasks (Brown & Heathcote, 2008). Moreover, LBA parameters have recently been used to identify neural correlates of the cognitive processes that drive decision-making behavior (e.g., Forstmann et al, 2008; 2010). However, the current implementation of LBA does not allow one to estimate the hypothesized trial-to-trial fluctuations in the model parameters. Here we present a new method to estimate single-trial LBA parameters. Parameter recovery studies indicate that an essential part of the variance in the data can be captured, supporting the usefulness of this approach. The single-trial parameters that we obtain from the LBA model can be applied to study trial-to-trial fluctuations in neural activation and shed light on how these fluctuations relate to online adjustments in the decision making process. We present data from a speed-accuracy tradeoff experiment that illustrates how single-trial LBA parameters can be used to study the neural correlates of decision-making.

(113)
Sunday, 11:45
Distler

Theory testing with the prior predictive. Wolf Van Paemel, *University of Leuven, Belgium*. Many existing model selection methods do not consider whether a good fit is meaningful and are insensitive to

the prior. I propose the prior predictive test, which is based on the prior predictive distribution. A model is evaluated by considering the meaningfulness of a good fit and by investigating whether the observed data are among the central predictions of the model. A good fit is only meaningful and impressive if it has been demonstrated that plausible outcomes exist that are not among the central predictions of the model. Upon observing data, three situations can occur. First, if the observed data are not among the central predictions of the model, the model is invalidated. Second, if the observed data are among the central predictions of the model, and a good fit is meaningful, the model is supported. Third, if the observed data are among the central predictions of the model, and a good fit is not meaningful, the model is neither supported nor invalidated. The prior predictive test is sensitive to the prior and takes the plausibility of data into account. An application example focusing on category learning demonstrates the potential of the prior predictive test for testing psychological models.

(92)
Monday, 10:00
Cohen

A new measure for post-error slowing: Robustness to global changes in task performance. Don van Ravenzwaaij, *University of Amsterdam*, Gilles Dutilh, *University of Amsterdam*, Eric-Jan Wagenmakers, *University of Amsterdam*. In response time tasks, people tend to slow down after making an error, a phenomenon generally known as post-error slowing (PES). Usually, PES is quantified as the difference between post-error RT and post-correct RT. However, there appears to be no particular reason why this measure is preferred over alternative methods, such as the difference between post-error RT and pre-error RT. In this study, we show that the traditional way of quantifying PES is prone to contamination by global changes in performance over the course of a task, such as dwindling attention or increased task aptitude. Using the drift diffusion model, we simulate different types of global changes in performance over trials and show how these affect the traditional measure of PES, but not the proposed new measure. Furthermore, we illustrate the differential existence of both types of PES in an empirical dataset.

(86)
Monday, 11:45
Distler

Between-trial effects in perceptual decision making - a model-based EEG analysis. Marieke van Vugt, *University of Groningen*, Patrick Simen, *Princeton University*, Jonathan Cohen, *Princeton University*. Every decision we make is influenced by various forms of prior information based on what happened before. In a drift diffusion model, those expectations are reflected either in a change in the starting point of evidence accumulation or in a change in the decision threshold and are modelled with stochastic noise. Finding the neural locus of decision biases may eventually allow us to read out trial-to-trial variability in prior information from brain activity. In this study, we looked for such a neural locus of decision biases. Participants viewed random dot kinematograms and decided on its direction of motion. We ma-

nipulated the amount of prior information by manipulating the balance between left- and right-ward moving stimuli. We then asked whether lateralized pre-stimulus oscillatory activity would covary with these behaviorally-induced response biases. We found that the amplitude of pre-stimulus 28–90 Hz gamma oscillations covaried with response bias. We discuss possible implications of this finding for accumulator models of decision making.

(129)
Sunday, 4:10
Alumni

Numerical methods for fitting the Linear, Competitive Accumulator Model. Joachim Vandekerckhove, *University of Leuven, Belgium*, Don van Ravenzwaaij, *University of Amsterdam*, Scott Brown, *University of Newcastle, Australia*, Eric-Jan Wagenmakers, *University of Amsterdam*. The Linear, Competitive Accumulator (LCA) model is a neurally inspired sequential-sampling model for human decision making. While the LCA model is biologically plausible and includes many desirable features such as lateral inhibition and leakage, fitting the model is a challenging task for which no standard methods have been published to date. We apply simulation-based Bayesian and non-Bayesian methods to fit the LCA model to empirical choice response time data. The present paper describes different numerical procedures to fit the model, with a focus on their relative efficiency.

(87)
Monday, 4:30
East Sophia Gordon Bldg.

Grasping isomorphism: review of Hinton's "Learning distributed representations of concepts". Sergio Varona-Moya, *University of Malaga*, Pedro Cobos, *University of Malaga*. Multilayer perceptron networks' ability to perform sensible inferences by analogy was pointed out by the results of knowledge generalization tests from one domain to a structurally identical second domain carried out by Hinton (1986). Due to its methodological weaknesses, a comprehensive review of this work has been tackled in order to find statistically grounded answers to the questions posed by the author. Using the same network architecture and learning procedure, 500 simulations, starting from random weights and biases, were trained in the two structurally identical family trees task problem proposed by Hinton. In this review (1) coding of implicit task-relevant pattern features in internal activation states was assessed by discriminant analysis; (2) the degree of isomorphism between the two family trees grasped by a simulation was computed through an ad hoc algorithm applied to principal component analysis scores of hidden units' activation vectors and (3) network's ability to perform inferences by analogy was tested with a corrected version of generalization tests on a mixed factorial design basis. The main conclusions are these: (1) networks reach highly structured internal activation spaces in accordance with implicit useful pattern features; (2) isomorphism grasp is not as consistent a property as Hinton suggested, as it arranges in a normal distribution in the sample, and (3) statistically significant interaction effects between isomorphism

grasp and learning the second family tree prove that the degree of structural similarity discovered by a network modulates its ability to generalize from one tree to another.

(137)
Saturday, 11:25
Alumni

A thought-mode dependent identification of context relevance and exemplar representativeness for concepts. Tomas Veloz, *University of British Columbia*, Liane Gabora, *University of British Columbia*. Dual processing theories posit that we shift between an analytic, convergent mode to apply conventional problem solving strategies, and an associative, divergent mode to break out of a rut and see things anew. We present a tentative mathematical model of this using of the State-COntext-Property (SCOP) theory of concepts. A concept is modeled as existing in a state of potentiality until it interacts with a context, causing it to collapse to an exemplar state. Collapse is modeled by a state transition function analogous to the quantum collapse to an eigenstate from the ground state by measurement. We propose that in analytic thought one evoke an exemplar of a concept that is typical in contexts whose meaning is more aligned with the concept, while in associative thought, one evoke an exemplar atypical in the more aligned contexts, but typical in a potentially relevant context. Using data from studies in which participants were asked to rate the typicality of exemplars of a concept for different contexts, we built the transition probabilities from the state of potentiality to the exemplars. The mode of thought is modeled by a parameter $p \in [0, 1]$. We define a measure of context-relevance from p and the typicality distribution of exemplars. When $p = 0$, the context-relevance reflects alignment between the context and concept meanings, modeling analytic thought. Associative thought is modeled by increasing p, thus flattening the distribution of context relevance values, and increasing the representativeness of new exemplars. We next model divergent thought as an entangled state of exemplars

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Saturday, 3:30
Alumni

The Ising Decision Maker: a thermodynamical approach to decision RT modeling. Stijn Verdonck, *University of Leuven, Belgium*, Francis Tuerlinckx, *University of Leuven, Belgium*. The elementary decision making process is among the most intensively investigated concepts in the current field of psychology. The traditional modeling approach of defining abstract information accumulators on a macroscopic level (with the Ratcliff diffusion model as a prime example) has been successful in describing a number of RT phenomena. Mostly formulated as linear dynamical systems, these models are relatively easy to manipulate and parametrize, and therefore a popular choice for modeling RT data. The computational properties of any biological system however, emerge from a microscopic, in this case neural, level. In recent years, a plausible integrate and fire network has been proposed modeling the 2AFC process bottom up (Wong & Wang, 2006), but its computational complexity renders it less attractive for the psy-

chological researcher desiring a efficiently estimable model. Furthermore, a number of issues are left unaddressed (e.g., fast error RTs, SAT).To alleviate these problems, we propose an abstract version of this network based on the Ising model: a collection of N pairwise interacting neuron-bits. While retaining the basic qualities of a noisy multiple attractor network, it is not concerned with the concrete mechanisms of elementary neuronal interaction. As a thermodynamical system, the N-dimensional microscopic description can be reduced to a two-dimensional macroscopic model, closely connected to a set of two non-linear diffusion equations. It will be shown that the Ising Decision Maker is able to reproduce many empirical phenomena, among which fast and slow errors, SAT and Weber's law.

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Sunday, 12:05
Distler

Model Comparison Is Judgment and Model Selection is Decision Making. Jay Verkuilen, *The City University of New York (CUNY)*, Clintin Davis-Stober, *University of Missouri*, Nicholas Brown, *University of Missouri*. Model Comparison (MC) and Model Selection (MS) are now commonly used procedures in the analysis of psychological data. However, a number of puzzling questions seem to remain largely unexamined, many of which parallel issues that have been studied empirically in the judgment and decision making literature. In general, both MC and MS involve multiple criteria and are thus likely to be subject to the same difficulties as many other multi-criteria decision problems. For example, standard MS rules based upon Akaike weights employ a variation of Luce's choice rule. The fact that Luce's choice rule was constructed to encapsulate a probabilistic version of the 'independence of irrelevant alternatives' (IIA) condition has a number of consequences for the choice set of models to be compared. Contractions and dilations of the choice set are likely to be problematic, particularly given that information criteria measure only predictive success and not other aspects of the problem that are meaningful but more difficult to quantify, such as interpretability. We offer some examples based on simple models to show the general problem.

(62)
Monday, 11:25
Distler

Modeling the relationships between iron and behavior in the context of iron depletion and repletion. Michael Wenger, *The University of Oklahoma*, Julie Hammons, *Cornell University*, Samuel Scott, *The Pennsylvania State University*, Jere Haas, *Cornell University*, Laura Murray-Kolb, *The Pennsylvania State University*. Iron deficiency (ID) is the world's single most-prevalent nutrient deficiency. The functional consequences of ID on brain state, with concomitant effects on perception and cognition, have until recently received rather limited attention. However, the small number of human studies that have examined these questions have shown both reliable deficits in perception, attention, learning, and memory in ID and reliable improvements when iron status is normalized. The neurophysiological mechanisms under-

lying these behavioral changes are poorly understood both in terms of individual biological factors and their potential interrelations. We present here a computational model linking basal ganglia, thalamus, hippocampus and cortical regions that is capable of representing competing hypotheses for the physiological mechanisms of changes in brain iron and linking those hypotheses to predictions for behavior and electrophysiology (EEG). To our knowledge, it is the first and only model for the neurophysiological mechanisms of brain iron capable of bridging these levels of analysis. The modeling approach is based on the dynamic integrate-and-fire population models developed by Ashby and colleagues, and includes mechanisms that have been shown in animal studies to be sensitive to brain iron status. The modeling approach is shown to be capable of relating hypothesized changes in brain neurophysiology to concurrent measures of behavior and EEG first in the context of iron repletion in adults and second in critical periods of development for iron depletion in infants.

(67)
Sunday, 3:10
Distler

Fitting drift-diffusion models in a hierarchical Bayesian framework: methods and applications. Thomas Wiecki, *Brown University*, Imri Sofer, *Brown University*, Michael Frank, *Brown University*. We present an open-source software suite written in Python called HDDM (Hierarchical Drift Diffusion Modeling) that allows users to easily perform hierarchical Bayesian inference on drift-diffusion decision making models. Drift-diffusion models (DDM) account for the full reaction time (RT) distributions of correct and error responses in 2-alternative-forced-choice tasks. The parameters of the DDM have a direct mapping onto psychological processes underlying decision-making. Classically, finding the set of parameters that best explain a subjects RT distribution is done via maximum likelihood (ML) methods. However, hierarchical Bayesian parameter estimation offers some critical advantages compared to ML: (i) subject parameters are not fit separately but are constrained by group level parameters, thereby sharing statistical strength; and (ii) the procedure offers a principled approach for estimating the full posterior distribution of parameter values (for both subjects and groups) instead of just the single maximum likelihood value. Current software packages for fitting DDMs such as fast-dm and DMAT are constrained to ML or other related optimization techniques. HDDM is a novel software package with focus on ease-of-use, flexibility and computational efficacy that relies on Markov-Chain Monte Carlo sampling methods implemented by PyMC. In addition to the software package we present the extension of the DDM to a novel domain unrelated to decision making: by fitting the HDDM to simulated data from a biological constrained computational model of the antisaccade task we find a direct link between neurobiological and psychological processes.

(57)
Monday, 3:30
Cohen

A random-walk model for multi-alternative preferential choice.

Lena Wollschlaeger, *Jacobs University, Bremen*, Adele Diederich, *Jacobs University Bremen*. In order to simulate reaction times and choice probabilities in multi-alternative preferential choice, we use a multi-dimensional random-walk-model. Transition probabilities depend on the values of the alternatives on multiple attributes, as in Diederich (1997). Leakage, inhibition and noise constrain the information sampling process. Inhibition can be implemented either locally as in Decision Field Theory (Roe, Busemeyer and Townsend, 2001) or globally as in the Leaky Competing Accumulator Model (Usher and McClelland, 2004). For choices between three alternatives, the model can simulate similarity, compromise and attraction effects. Simulation of choices with optional or fixed stopping times between four or more alternatives is also possible. Furthermore, numerical estimation of expected reaction times (in the optional stopping time case) and choice probabilities is computationally feasible.

(134)
Monday, 10:45
Distler

Testing predictions of Event Related Potentials from the eSTST model supports a prior entry model of lag 1 sparing. Brad Wyble, *Syracuse University*. Computational neuroscience allows us to create formally specified theories of the functional architecture of visual attention that have direct analogs to neural mechanisms. This neural plausibility allows a valuable source of additional constraints as provided by neuroscientific measures of brain function, such as EEG and fMRI. In this case, the question being addressed is how we perceive temporal order in rapidly presented streams of stimuli This talk will focus on recent tests of the eSTST model, which simulates the temporal deployment of attention in RSVP tasks such as the attentional blink. This model includes an explicit simulation of the time course of the underlying neural mechanisms involved in attention and perception. It can thereby provide predictions about both EEG and behavioral data concurrently. One of the predictions that we have recently tested concerns temporal order errors for two targets presented in close succession in an RSVP stream (often referred to as lag 1 sparing). This model correctly predicted both the behavioral consequences of changing the speed of the RSVP stream on the frequency of such errors, but it also correctly predicts highly reliable differences in the shape of the P3 component between correct and order-reversed trials. These results support the validity of the eSTST simulation of temporal order perception in single stream RSVP tasks, which is implemented using a mechanism with resemblance to theories of prior entry in spatial TOJ tasks.

(108)
Sunday, 10:00
Alumni

Multidimensional information processing: An extension of Systems Factorial Technology. Haiyuan Yang, *Indiana University*, Mario Fific, *Max Planck Institute*, James Townsend, *Indiana University*. Systems Factorial Technology (SFT) is a general set of tools for studying cognitive processes. Highlights of SFT are the ability to distinguish between paral-

lel, coactive and serial processing as well as to determine the stopping rule. One of the most fascinating predictions in SFT is that in the serial exhaustive model, the Survivor Interaction Contrast (SIC) function wiggles above and below 0, with equal area on either side. This renders the serial exhaustive model distinguishable from other models (Townsend & Nozawa, 1995). However, the exact form of the SIC signature in serial exhaustive model has been unclear. I. The present study thus began by exploring the precise behavior of the serial exhaustive SIC function for $n = 2$. We found that: A. There must be an odd number of crossings for any set of component distributions. B. A rather mild condition known as log-concavity, is sufficient as a guarantor of a single zero crossing. II. Furthermore, up until now, there has been a lack of knowledge concerning how the architectural signatures act when the number of processes is varied. Thus, the second major part of the study pursued this issue. A. We provide a generalization of the SIC function to arbitrary dimensions, as well as a theoretical analysis of the SIC in its generalized form for both parallel and serial models in conjunction with both the minimum time and maximum time stopping rules. B. Based on rigorous proofs, we show that even in the multidimensional case, SFT is a valid tool in distinguishing mental architectures.

(55)

Monday, 9:40

Cohen

Relative change probability affects the decision process of detecting multiple feature changes. Cheng-Ta Yang, *National Cheng Kung University*. In real world, a change usually consists of multiple feature changes and one feature change may occur more frequent than the other. For example, when one changes his/her hair style, hair shortening is more frequent than hair coloring. However, no prior studies have examined how relative change probability may affect the decision process of detecting multiple feature changes. The present study manipulated the relative change probability between two features to examine how it affects the process characteristics of a decision mechanism. The systems factorial technology (Townsend & Nozawa, 1995) was adopted to design experiments, analyze data, and make inferences. Participants were required to detect changes in orientation or spatial frequency of a Gabor patch. The presentation frequency of two feature changes was equal in Experiment 1, and a frequency change was three times more frequent than an orientation change in Experiment 2. Results showed that participants adopted parallel self-terminating processing in Experiment 1, and they altered their decision strategy to serial self-terminating processing in Experiment 2. These results support the relative saliency hypothesis (Yang, in press) which states that the participants' decision strategies are adopted depending on the relative saliency. Specifically, parallel processing is adopted when two features are equally salient, and serial processing is adopted when relative saliency exists. Relative change probability affects relative saliency between features and consequently influences the adoption of a decision strategy in the context of change detection.

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Monday, 11:25

East Sophia Gordon Bldg.

The Development Of Context Use And Three Way Bindings In Episodic Memory. HYUNGWOOK YIM, *The Ohio State University*, SIMON DENNIS, *The Ohio State University*, VLADIMIR SLOUTSKY, *The Ohio State University*. To address the mechanism underlying the development of episodic memory, the current study used a modified list learning paradigm for children (i.e. ABCD, ABAC, ABABr) and compared the performance of 4 year-olds, 7 year-olds, and adults. The results show that only the ABABr condition, which involves a 3-way binding structure, differed across age. Additionally, a proposed computational model decomposed the binding strengths involved in the given tasks and made it possible to compare the changes in these binding strengths. The model shows that though all groups have similar item binding strength, the context binding and 3-way binding strengths developed throughout development. It is concluded that the developmental changes in the current episodic memory tasks involve encoding abilities related to attention. Moreover, the role of pre-frontal cortex in the task is discussed comparing previous neuropsychological researches.

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Saturday, 9:00

Alumni

Why every pop song sounds the same: Revealing melodic expectations through cultural transmission. JULIA YING, *University of California, Berkeley*, JOSEPH AUSTERWEIL, *University of California, Berkeley*, THOMAS GRIFFITHS, *University of California, Berkeley*. Psychological theories of music appreciation assert that listeners form expectations based on the notes they previously heard. Recently, statistical analyses of the structure of music have identified the distributions of pitches and intervals in European folk melodies (Schaffrath, 1995; Huron, 1999) and demonstrated that Bayesian models using these distributions can infer properties of the melodies, such as their key (Temperley, 2008). This raises the question of whether people make similar inferences by internalizing these 'natural statistics' of their musical environment. To explore this hypothesis, we used the iterated learning method introduced by Kalish, Griffiths, and Lewandowsky (2007) to simulate the process of cultural transmission, trying to estimate the prior distribution on melodies assumed by a group of participants. Each participant hears a set of melodies, and is asked to replace a muted note in each melody. The resulting melodies are then given to the next participant, with another note muted at random. If people fill in these notes by Bayesian inference based on a prior distribution on music notes and intervals and the data provided by the other notes, then this process will eventually converge on a set of melodies that are sampled from the prior (Kalish et al., 2007). The statistics of the melodies produced by our participants converge towards those of folk melodies over time, suggesting that people have internalized information from their musical environment. Our results also indicate how cultural transmission of music can shape that music to match people's expectations.

(102)
Saturday, 10:45
Alumni

Probabilistic Models of Grounded Word Learning through Sensorimotor Child-Parent Interaction. Jun-Ming Xu, *University of Wisconsin, Madison*, Xiaojin Zhu, *University of Wisconsin, Madison*, Chen Yu, *Indiana University*. The goal of the study is to use mathematical and computational approaches to understanding the mechanisms through which word learning is grounded in multimodal social interactions between young children and their parents. We designed and implemented a multimodal sensing environment consisting of two head-mounted mini-cameras that are placed on both the child's and the parent's foreheads, motion tracking of head and hand movements and recording of caregiver's speech. Using this new sensing technology, we captured the dynamic visual information from both the learner's perspective and the parent's viewpoint while they were engaged in a naturalistic toy-naming interaction. We implemented various data processing programs that automatically extracted visual, motion and speech features from raw sensory data. Two computational models are developed that can predict the child's learning results based on sensorimotor features extracted from child-parent interactions. The first effort is based on an elastic-net regression model. Through the trained regression coefficients in the model, we discovered a set of perceptual and motor patterns that are informatively time-locked to words and their intended referents and predictive of word learning. The second model is a nonparanormal graphical model with each sensorimotor feature as a node in a graph. By inferring the graphic structure of this joint model, we further investigate how various features extracted jointly work together to lead to successful word learning. Those patterns provide quantitative measures of the roles of various sensorimotor cues that may facilitate learning, which sheds lights on understanding the underlying real-time learning mechanisms in child-parent social interactions.

(98)
Sunday, 11:05
Alumni

Modeling the Influence of Frequency and Discrimination on Associations Between Concepts and Features. Matthew Zeigenfuse, *Michigan State University*. Associations between concepts and features are an integral part of many models similarity, categorization, decision-making and information search and basic level preference. Previous work suggests at least two factors influence the association between a concept and feature, the relative frequency with which the concept and feature co-occur and the ability of the feature to distinguish the concept from other concepts. In this talk, a model generalizing existing accounts of association, such as cue validity, collocation, and category utility, based on these complementary factors will be presented. This model can account for human associations as well as being able to explain differences between individuals and conceptual domains in terms of differences in attention to relative frequency and ability to discriminate. Additionally, it has the potential to account for contextual effects in similarity and categorization by

providing a theory of how context affects a concept's mental representation.

(167)
Monday, 4:10
East Sophia Gordon Bldg.

Regularized Learning in Banach Spaces and Reference-Representational Biduality. Jun Zhang, *University of Michigan*. Regularized learning is the contemporary framework for learning to generalize from finite samples (classification, regression, clustering, etc). Here the problem is to learn an input-output mapping $f : X \to Y$, either scalar-valued or vector-valued, given finite samples $[(x_i, y_i), i = 1, \cdots, N]$. With minimal structural assumptions on X, the class of functions under consideration is assumed to be in a Banach (especially, Hilbert) space B of functions. The learning-from-data problem is then formulated as an optimization problem in such a function space, with the desired mapping as an optimizer to be solved, where the objective function consists of a loss term $L(f)$ capturing its goodness-of-fit (or the lack thereof) on given samples $[(f(x_i, y_i), i = 1, \cdots, N]$, and a penalty term $R(f)$ capturing its complexity based on prior knowledge about the solution (smoothness, sparsity, etc). For well-founded mathematical reasons, the regularizer (second term) is often taken to be the norm of B, or a monotone transformation ϕ thereof: $R(f) = \phi(||f||)$. This program has been successfully carried out for the Hilbert space of functions, resulting in the celebrated Reproducing Kernel Hilbert Space (RKHS) methods in the contemporary machine learning literature. Working with collaborators, I have recently removed the Hilbert space restriction, i.e., the existence of an inner product, and showed that the key ingredients of this framework (reproducing kernel, representer theorem, feature map, but not "kernal trick") remain to hold for a Banach space that is uniformly convex and uniformly Frechet differentiable. Central to our development is the use of a semi-inner product operator and duality mapping for a uniform Banach space in place of an inner-product for a Hilbert space. Our approach will provide a unified viewpoint for similarity and feature representation/selection in categorization, the former implemented by the notion of reproducing kernels (resulting from regularizing $L2$-norm) and the latter linked with the notion of sparsity (resulting from regularizing $l1$-norm), which have so far been investigated under different theoretical foundations. Our results also deepened the mathematical foundation of the Principle of Reference-Representational Biduality (Zhang, 2004) originally proposed for the dual scaling between reference and comparison stimuli in multi-dimension psychological spaces.

(56)
Monday, 3:10
Cohen

Optimal sequential sampling models for structured cue-based environments. Shunan Zhang, *University of California, Irvine*, Michael Lee, *University of California, Irvine*. We consider a two-alternative forced choice task, where the decision maker has to choose the larger one from a pair of German cities, based on the information of presence or absence of a common set of binary cues to be collected

in sequence. We study the optimal solution to this problem that corresponds to some psychologically meaningful utility, and show that the optimal solution generates adaptive boundaries when it is associated with the Random Walk Model of decision making. We also show that the optimal decisions vary with different cue orders, and are affected by both cue discriminabilities and cue validities. In one special case, the optimal solution yields the well-known Take the Best heuristic.

(40)
Saturday, 9:20
Distler

Quantitative Testing of Decision Theories: A Bayesian Counterpart. Chris Zwilling, *University of Illinois, Urbana-Champaign*, Daniel Cavagnaro, *The Ohio State University*, Michel Regenwetter, *University of Illinois*. We consider quantitative tests of leading decision theories, including Expected Utility theory (EUT), Cumulative Prospect theory (CPT) and the Transfer-of-Attention-Exchange model (TAX), within a Bayesian framework. Previous research by a variety of scholars has shown that specifying an appropriate probabilistic structure is a crucial step in testing algebraic decision theories against real data. Here, we discuss a general methodology that accommodates 'distance-based,' 'aggregation-based,' and 'mixture-based' probabilistic specifications. At the 2010 meeting, two of the authors presented a frequentist analysis of these models. All three models, EUT, CPT, and TAX performed very poorly in that quantitative analysis. That analysis used new laboratory data and several probabilistic specifications of certain functional forms for the three theories. Here, we provide a corresponding Bayesian analysis of the same theories on the same data and contrast our findings with the frequentist results we obtained previously. We discuss differences and commonalities between the frequentist and Bayesian analyses.

Abstracts For Posters

All Posters in Theater Lobby Area

(Poster abstracts in alphabetical order)

(133)
Saturday, 5:00-6:30
Board C #4

Associative information in memory: Evidence from cued recall. William Aue, *Syracuse University*, Amy Criss, *Syracuse University*, Nicholas Fischetti, *Syracuse University*. The representation of item and associative information in episodic memory was investigated using a cued recall paradigm. During the experiments, participants studied two lists constructed such that some items presented in a pair during List 1 were rearranged to create new pairs in List 2. Critically, List 1 and 2 could contain the same or different type of pair (e.g., word-face v. word-word pairs). Participants were then tested on their memory for the most recent list. Cued recall performance was evaluated with respect to whether pairs were repeated in the same or different pair types across lists. Implications for current approaches for representing associative information in models of memory are discussed.

(50)
Saturday, 5:00-6:30
Board A #1

Using Reverse Hazard to Ascertain Risky Weighting Functions in Judgment Under Uncertainty. Daniel Barch, *Tufts University*, Richard A. Chechile, *Tufts University*. For continuous probability distributions, the reverse hazard is defined as the ratio of the probability density at point x and the cumulative probability at point x: $\frac{f(x)}{F(x)}$, whereas the hazard is defined as the ratio of the probability density and the survivor function, that is, $\frac{f(x)}{1-F(x)}$. Reverse hazard functions can differ greatly even among highly similar cumulative distributions (Chechile, 2011). The current research assessed various risky weighting functions for binary lotteries in terms of their reverse hazard properties. Risky weighting functions are the weighting coefficients of the utilities of outcome magnitudes. Candidate functional forms for the risky weighting function, including those previously discussed in the literature, were evaluated through empirically estimated reverse hazard functions. These reverse hazard estimates were based on the results of a novel gamble-matching paradigm. Our research provides strong support for a weighted-power model for the risky weighting function, i.e., $F(p) = \frac{p^a}{p^a+(1-p)^a}$.

(110)
Saturday, 5:00-6:30
Board E #2

When 'Improper' is Proper: A Comparison of Different Weighting Rules to Ordinary Least Squares. NICHOLAS BROWN, *University of Missouri*, CLINTIN DAVIS-STOBER, *University of Missouri*. Within the context of multiple regression, Dawes (1979), among others (e.g., Wainer, 1976), argued that simple "improper" weighting schemes, such as equal weighting, may perform as well as, or better, than Ordinary Least Squares (OLS) estimation. These weighting schemes are "improper" in the sense that they are determined a priori, often according to some decision rule or heuristic. We explore the predictive accuracy of a host of improper weighting schemes on a range of existing data sets. We employ the methodology of Davis-Stober (2011) and Davis-Stober, Dana, and Budescu (2010a; 2010b) to evaluate the performance of these different choices of improper weights and we compare their relative performance to that of OLS.

(77)
Saturday, 5:00-6:30
Board D #4

A Phase Transition Model for the Speed-Accuracy Trade-Off. GILLES DUTILH, *University of Amsterdam*, ERIC-JAN WAGENMAKERS, *University of Amsterdam*, INGMAR VISSER, *University of Amsterdam*, HAN VAN DER MAAS, *University of Amsterdam*. Most models of response time in elementary cognitive tasks implicitly assume that the speed-accuracy trade-off is continuous: when payoffs or instructions gradually increase the level of speed stress, people are assumed to gradually sacrifice response accuracy in exchange for gradual increases in response speed. This trade-off presumably operates over the entire range from accurate but slow responding to fast but chance-level responding (i.e., guessing). Here, we challenge this assumption of continuity and propose a phase transition model for response times and accuracy. Analogous to the fast guess model (Ollman, 1966), our model postulates two modes of processing: A guess mode and a stimulus controlled mode. From catastrophe theory we derived two important predictions that allowed us to test our model against the fast guess model and against the popular class of sequential sampling models. The first prediction - hysteresis in the transitions between guessing and stimulus controlled behavior - was confirmed in an experiment that gradually changed the reward for speed versus accuracy. The second prediction - bimodal response time distributions - was confirmed in an experiment that required participants to respond in a way that is intermediate between guessing and accurate responding.

(65)
Saturday, 5:00-6:30
Board E #3

Using visual search task to gather information about dissimilarities among stimuli of different complexity. ILYA EDRENKIN, *Lomonosov MSU*. Information about dissimilarities among stimuli is useful in research of sensory systems. Data reduction methods like multidimensional scaling are used to reveal several filters that perform discrimination from dissimilarity data. Different ways of measuring differences among stimuli exist, but they have some limitations due to

cognitive influences on sensory processes. A novel method that lacks this disadvantage was developed, based on the visual search task performance. It is based on obvious and also empirically proven fact that similarity between target and distractors in 'pop-out' search affects its efficiency. Thus measuring visual search performance for various target-distractor pairs can provide dissimilarity data. Three groups of stimuli are considered: lines differing by brightness, spatial orientation or both. A 1-dimensional geometrical model for brightness discrimination, 3-dimensional model for orientation discrimination, and 4-dimensional model for complex stimuli discrimination are built. A filter that is tuned to discrimination of oblique lines from non-oblique lines regardless of exact orientation is found, that corresponds neurophysiological data concerning multiple-tuned neurons. Also, some interaction between brightness and orientation encoding are found. Visual search asymmetry data is considered as a source of information in the way of feature integration theories. Search asymmetry profiles are built and analyzed for different stimuli. Electrophysiological ERP research is performed, that showed correlation between P300 component amplitude, visual search efficiency and target-distractor similarity. The proposed method showed to gain credible results. Thus it can be used as an instrument of measuring dissimilarities among stimuli.

(122)
Saturday, 5:00-6:30
Board B #4
Understand Age Related Memory Impairments: An Extension of the Context Maintenance and Retrieval Model. Karl Healey, *University of Pennsylvania*, Lynn Lohnas, *University of Pennsylvania*, Michael Kahana, *University of Pennsylvania*. Increased failure of episodic memory retrieval is one of the most salient and disturbing cognitive changes that occur as an individual ages. Cognitive gerontology has revealed a complicated pattern of both preserved and impaired aspects of episodic memory performance. For example, on the free recall task older adults show no deficit in initiating recall and using preexisting semantic associations to guide subsequent recalls. Older adults do, however, show a deficit in the use of new temporally defined (i.e., episodic) associations. Older adults also produce many more intrusions than younger adults, both from prior lists and from extra-experimental sources. Many theories have been proposed to account for age related memory impairments. Evaluating these theories is complicated by an incomplete understanding of the cognitive processes involved in the unimpaired memory system; unless embedded within a well-specified model of episodic memory it is difficult to determine if a theory can adequately capture the complex pattern of impaired and spared performance older adults show on memory tasks. However, recent theoretical advances, driven by new computational models of episodic memory encoding and retrieval processes, have greatly advanced our understanding of healthy episodic memory. We use one of these models, the Context Maintenance and Retrieval model, to translate several prominent theories of cognitive aging into quantitatively explicit predictions and test these

predictions against the behavior of older adults. Initial simulations suggest that most theories have difficulty simultaneously accounting for the full pattern of spared and impaired performance.

(36)
Saturday, 5:00-6:30
Board B #3

Estimating Individual Differences in a Rational Model of Memory. Pernille Hemmer, *Syracuse University*, Mark Steyvers, *University of California Irvine*. Bayesian models of cognition have experienced a recent upsurge in popularity in the cognitive sciences. Assuming that the mind solves inference problems in a Bayesian way, Bayesian models of cognition give a principled account of how we update our beliefs about the world given observed data and how our prior knowledge interacts with this data. For example, our earlier modeling work has explained effects of prior knowledge with a rational model of memory. In this approach, it is assumed that individuals solve the computational problem of memory recall by optimally combining the available information from episodic memory and prior knowledge. Here, we extend these rational models of memory by develop a framework using Bayesian estimation procedures within the rational model. Bayesian Data Analysis is applied directly to the observed data as a method to learn about the underlying psychological variables of the rational model i.e., Bayesian inference is used both as a model of the mind of the participant and for analyzing the data from the perspective of the experimenter. We will illustrate the usefulness of this procedure in a simple rational model of recall for the height of people. We present two different ways to evaluate individual differences in the rational model using the recursive approach, a mixture model allowing for two different groups of participants, and a continuous model where we infer the subjective prior for each individual subject. We also determine the proportions of episodic memory and prior knowledge in the recall process.

(120)
Saturday, 5:00-6:30
Board A #3

The scalar property in a deterministic timing system. Yohan John, *Boston University*, Daniel Bullock, *Boston University*. A central aspect of animal and human behavior is the ability to apprehend regularities in the environment and use them to guide actions. Common to all types of incoming information is the temporal dimension; an event unfolds in time, and often has a predictable temporal relationship with other events, including the animal's own behavior. The present work focuses on interval timing, which refers to the seconds-to-minutes range within which most voluntary actions take place. Instrumental conditioning tasks in animals and humans shed light on the underlying neural structures, pharmacology, and psychophysical properties associated with interval timing. In this study we investigate a key statistical regularity observed in interval timing studies: the scalar property, which is a temporal analogue of the Weber-Fechner law. In the past many models have operated at a coarse grain, providing parsimonious ways to fit cumulative experimental data. But parameters from psychological models cannot al-

ways be mapped easily onto neural architectures, and often make assumptions about underlying memory distributions that seem untenable in neurally inspired systems. We show that natural assumptions about neural timing mechanisms lead to the scalar property in a deterministic system. We frame the scalar property in terms of deterministic processes that can be realized in neural systems, rather than processes based on random sampling from a hypothetical memory distribution. We demonstrate the scalar property in a simple neural system in which timed responding is governed by a bounded integrator whose rate of integration is scaled by linearly encoded reinforcement rate.

(76)
Saturday, 5:00-6:30
Board B #2

MPTinR: An (almost) complete R package for analyzing MPTs. Henrik Singmann, *University of Freiburg*, David Kellen, *University of Freiburg*, Fabian Hoelzenbein, *University of Freiburg*, Christoph Klauer, *University of Freiburg*. We present a package for the analysis of (nonhierarchical) Multinomial Processing Tree (MPT) models for the statistical programming language R: MPTinR. MPTinR combines two approaches, extending the functionality of other software for MPTs: (1) ease of use and (2) amount of functionalities. Regarding (1), MPTinR offers seamless integration with R, with both model and (sequential equality and sequential inequality) restrictions being conveniently defined in external files (also compatible with previous software implementations; e.g., multiTree). Regarding (2), MPTinR automatically provides fits for single- and multi-individual data (optionally) applying both equality and inequality restrictions. Model selection can be achieved with AIC, BIC and, using the minimum description length based Fisher Information Approximation (FIA; using the algorithm by Wu, Myung & Batchelder, 2010, ported to R). FIA can be conveniently computed by means of a simple model file given that the model's context-free representation (Purdy & Batchelder, 2009) is automatically constructed from the equations. Furthermore, MPTinR offers data generation and (parametric and nonparametric) bootstrap functionalities for model inference. Several functionalities can be accelerated using multiple cores. The homepage of MPTinR (including download link and documentation) is: http://www.psychologie.uni-freiburg.de/Members/singmann/R/mptinr

(142)
Saturday, 5:00-6:30
Board C #3

Probed Recall: Empirical Evidence and Theoretical Implications. Asli Kilic, *Syracuse University*, Criss Amy, *Syracuse University*, Howard Marc, *Syracuse University*. One of the most prominent findings from free recall is the contiguity effect which refers to the tendency to recall an item from nearby study positions of the previously recalled item. There are two classes of memory models that can explain the contiguity effect in free recall: Causal models (SAM, Raaijmakers & Shiffrin, 1980, 1981; TCM, Howard & Kahana, 2002) and noncausal models (Davelaar et al., 2005). Causal

models suggest that a recalled item which is used as a probe to recall another item, changes the memory state at retrieval. On the other hand, noncausal models explain the contiguity effect as a result of the correlation between the memory states at study and test without specifying a causal effect of the probe item generated by the participant. In the current study, we developed a probed recall task in which the correlation between the study context and the test context was disrupted. In probed recall task, participants were given 6 lists of words to study. At test, they were presented with 3 words from each list as probe words which were randomized within and between lists. For every probe word presented, they were asked to recall another word that was from the same study list. The results showed both short-term and long-term contiguity effects, suggesting that the contiguity effect can be observed even when the memory states at study and test are not correlated. The probed recall task required participants to use the probe word to jump back in time and generate a word from the same study list.

(106)
Saturday, 5:00-6:30
Board D #1

The geometry of the perceived layout of a real 3D scene. Taekyu Kwon, *Purdue University*, Yun Shi, *Purdue University*, Yunfeng Li, *Purdue University*, Tadamasa Sawada, *Purdue University*, Zygmunt Pizlo, *Purdue University*. All of the previous models of visual space were non-Euclidean: projective with constant negative curvature, projective with constant positive curvature, projective with varying curvature and affine with depth being perceptually compressed or stretched. None of these models, however, was able to generalize beyond one type of very special and impoverished viewing conditions that were used to formulate a given model. In the present study we used real indoor scenes and unrestricted viewing. The subject was asked to draw a top view of the perceived layout of a room containing several pieces of furniture. The subject's performance was evaluated by comparing perceived pairwise distances between objects to the actual distances. In one condition, blind walking was used to estimate the overall scale of the visual representation. After the overall scale was normalized, the standard deviation of distance judgment was about 10% and it did not decrease noticeably by adding an affine transformation. The systematic bias was close to zero and there was no difference between monocular and binocular viewing with unrestricted head. Results of the subjects will be compared to the results of a robot, whose 3D vision is based on our computational model involving several visual and non-visual priors. Our evidence strongly suggests that under normal viewing conditions the subject's and the robot's visual space is Euclidean.

(88)
Saturday, 5:00-6:30
Board A #2

Magnitude Estimation on a Very Large Number Line. David Landy, *University of Richmond*, Aleah Goldin, *University of Richmond*, Noah Silbert, *University of Maryland*. A robust understanding of numbers on the scale of billions and millions are very important for under-

standing political, economic, and scientific issues; however, set sizes in this range are rarely if ever directly perceptually experienced. We report on large-number understanding by college students using model-based evaluation of the number line task (Siegler and Opfer, 2003). In this task, participants place a number on a line with marked endpoints, ranging from 1 to 1 billion. In our studies, subjects placed numbers on a line with marked endpoints. Some subjects estimated values of number words (e.g., 'billion'), while others estimated values of numerals. Despite the absence of feedback, there was strong evidence of strategy shifting over the course of the task in many participants; participants tended to strongly overestimate number magnitudes early in the experiment, shifting toward more normative, linear judgments by the end. The basic model we used to evaluate performance is a modified Spence power law model of proportion judgments (Barth and Paladino, 2011; based on Hollands and Dye, 2000). This model contains one parameter governing proportion estimation, and one reflecting the participant's estimate of the comparative magnitude of the right-hand endpoint (1 billion). We adapted this model to account for intra-experiment strategy shifts. Because substantial strategy shifts were observed in the absence of feedback, these results suggest that many individuals maintain an incorrect estimate of the magnitude of large numbers despite having the knowledge required to generate a correct estimate.

(125)
Saturday, 5:00-6:30
Board A #4

The Wisdom of Crowds with Iterative Communication. Brent Miller, *University of California, Irvine*, Mark Steyvers, *University of California, Irvine*. The average estimate of a group of individuals is generally more accurate than the estimates of the individuals themselves, a phenomenon commonly referred to as the 'wisdom of crowds.' While this has been shown to be true for many types of estimation tasks, they are generally of low dimensionality (i.e. probability judgments or single-point estimates) and involve subjects that do not communicate with one another. In this study, we examine group aggregation performance for more complex tasks, involving reconstructing the order of time-based and magnitude-based series of items from memory. In half of these tasks, subjects receive the previous subject's final ordering, allowing communication in a serial fashion. The aggregate of communicating subjects is more accurate than that of independent subjects. We introduce a Bayesian version of a Thurstonian model to show how each subject combines their individual, private knowledge with the previous individual's ordering. The model likewise shows that individuals can produce estimates in the shared information condition that are better for aggregating than independent estimates.

(11)
Saturday, 5:00-6:30
Board C #1

Symbolic Simulation: a neural account for algorithmic and controlled information processing in human brain. Nader Noori, *USC/Computer Science Department*, Laurent Itti,

USC/Computer Science Department. Recent findings of neuroimaging and patient studies suggest that brain regions with visual-spatial characteristics are involved in a wide range of memory tasks including those with no immediate visual-spatial features. Yet, exactly how these regions contribute to such tasks remains an open question. To address this question here we propose a framework for manipulation of items in memory which relies on registering memory items in a spatially-organized short-term memory store. Switching executive attention to memory items that need processing may then be embodied through shifting spatial attention towards those registry locations. This assumption suggests that a secondary executive memory task may interfere with visuospatial short-term memory selectively and independent of the load on executive attention. Experiments with human subjects verified these predictions. Our findings suggest that visuospatial short-term memory serves domain independent processes for memory manipulation in addition to domain specific functions that require temporary maintaining of spatial information.

(107)
Saturday, 5:00-6:30
Board D #2

Recovering a 3D shape from a single 2D image of a generalized cone. Yun Shi, *Purdue University*, Taekyu Kwon, *Purdue University*, Tadamasa Sawada, *Purdue University*, Yunfeng Li, *Purdue University*, Zygmunt Pizlo, *Purdue University*. Recovering a 3D shape from a single 2D image is an ill-posed problem. A priori constraints are required to produce a unique and correct solution. In our previous studies we proposed a computational model that recovers 3D mirror-symmetrical shapes from single 2D images. While objects such as animal and human bodies are mirror symmetric, their parts are characterized by translational symmetry. Objects that are translationally symmetric are called generalized cones (GC). In this study, we show how GCs can be recovered from a single orthographic image, and we describe human performance in recovering their shapes. Our stimuli are produced by swiping a planar shape (cross section) along a planar axis, which is a parabolic curve, with the following additional constraints: (i) all cross sections in a given GC have the same shape, but not size, and (ii) each cross section is perpendicular to the tangent of the axis. In each trial, the subject's task was to adjust two parameters of a response 3D shape to match the shape of a test stimulus: the slant of the axis and the aspect ratio of the cross section. The results show that Generalized Cones are perceived very reliably. I will discuss these results in the context of previous research on perception of discrete translational symmetry (slant from texture).

(49)
Saturday, 5:00-6:30
Board B #1

Short-term changes in explicit and implicit memory: An application of the IES model. Lara N. Sloboda, *Tufts University*, Richard A. Chechile, *Tufts University*. The IES model is a multinomial processing tree (MPT) model that is designed to obtain separate estimates for explicit memory, implicit memory, fractional storage, and non-storage. The IES model

is based on a novel testing procedure that involves yes/no recognition with confidence ratings, as well as a series of contingent forced-choice tests. With explicit storage the target is fully encoded, resulting in correct recognition of the item with high confidence, and the selection of the item on a forced-choice test. With implicit storage, the encoding is a faint residue of the full target, and is unable to support confident, correct recognition. Despite the participants' stated lack of knowledge of the target, when forced to choose among items, this faint residue results in a correct forced-choice response. With fractional storage, only a component of the target is stored, but this information can be used to reject some foils. Non-storage corresponds to no target information being stored and results in chance-level performance on all testing. The IES model was applied to an examination of memory retention with five short-term intervals. The memory components measured by the IES model revealed a different retention pattern for each of the memory components.

(16)
Saturday, 5:00-6:30
Board E #4

Training children to alter their representation of numbers using Adaptive Experimental Design. Yun Tang, *The Ohio State University*, Christopher Young, *The Ohio State University*, Jay Myung, *The Ohio State University*, John Opfer, *The Ohio State University*, Mark Pitt, *The Ohio State University*. In this study we explore an adaptive experimental design (AED) approach for optimizing experimental designs to help the children acquire the desirable (linear) numerical representation. Studies on the development of numerical representations typically find that young children would incorrectly estimate numerical magnitudes to increase logarithmically with actual value before later learning the correct, decimal system (Siegler & Opfer 2003). Recent evidence in the literature suggests that a rapid and broad adoption of linear representations can be induced in situ by providing feedback on a few key numbers. In the present investigation we adopt a previously developed AED procedure to facilitate representational change for elementary school children. The procedure of an adaptive numerical experiment infers a learner's representation but also predicts the feedback that is most likely to induce representational change. A between-subjects experiment was conducted under three design conditions: adaptive optimal designs, designs derived from expert's analysis, and commonsense designs (i.e. quartiles). We will discuss the pros and cons of each design strategy.

(116)
Saturday, 5:00-6:30
Board D #3

A Bayesian Test for the Hot Hand Phenomenon. Darja Tutschkow, *University of Tuebingen*, Conor Dolan, *University of Amsterdam*, Gilles Dutilh, *University of Amsterdam*, Ruud Wetzels, *University of Amsterdam*, Sophie van der Sluis, *Free University, Amsterdam*, Eric-Jan Wagenmakers, *University of Amsterdam*. In many sports it may appear that performance is streaky, as players can alternate runs of good performance with runs of poor performance. The idea that a

player can be either in a hot state (i.e., perform well) or in a cold state (i.e., perform poorly) is known as the 'hot hand phenomenon'. Here we propose a Bayesian test to quantify the statistical evidence for and against the hot hand phenomenon. Specifically, we used the Bayes factor to compare a three-parameter two-state Bernoulli Hidden Markov Model (HMM) to a baseline model that assumes constant performance. The HMM has two parameters that represent the probability of a 'hit' in each state and a third parameter that represents the probability of staying in a state. The advantage of using an HMM in the context of the hot hand phenomenon(as opposed to commonly used statistics such as the length of the longest run of successes) is that the HMM structurally corresponds to the definition of a streaky player. The advantage of using the Bayes factor is that it naturally accounts for differences in model flexibility. Performance of the new test is explored in simulation studies and real data examples involving baseball, basketball, and experimental psychology.

(145)
Saturday, 5:00-6:30
Board E #1

Relating EEG/ERP measures of visual working memory capacity to behaviorally derived measures in a visual change detection task. Li Zhou, *Miami University*, Robin Thomas, *Miami University*. Various behaviorally based measures of visual working memory capacity have been proposed and studied extensively (Pashler, 1988; Cowan, 2005; Rouder et al., 2008). In addition, several measures based upon EEG and ERP data have also been explored as correlates of various concepts of cognitive load and/or working memory capacity based on spectral representation of EEG data (Gevins & Smith, 2003), nonlinear time-series analysis (Lamberts, et al., 2000), and measures based on ERPs (Luck, 2005). We explore several of these EEG/ERP measures in their relative ability to relate to the different behaviorally derived measures of working memory capacity in the visual change detection paradigm.

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We ask that the last presenter in each session act as chair, and keep time for the session.

Time	Saturday, Distler	Saturday, Cohen	Saturday, Alumni
9:00	**Regenwetter:** Rationality or Irrationality of Preferences? A Probabilistic Specification of Tversky's...	**Menneer:** Twenty-five Years of General Recognition Theory: Approaches and Tools	**Ying:** Why every pop song sounds the same: Revealing melodic expectations through cultural...
9:20	**Zwilling:** Quantitative Testing of Decision Theories: A Bayesian Counterpart	**Ashby:** A Brief History of General Recognition Theory	**Miller:** Improving Between-Individual Wisdom using Within-Individual Crowds
9:40	**Srivastava:** Cognitively efficient need satisfaction: a novel intrinsic reward model explains...	**Silbert:** Two hierarchical Bayesian General Recognition Theory models	**Batchelder:** Cultural Consensus Theory: Comparing Different Concepts of Cultural Truth
10:00	**Cavagnaro:** An adaptive experiment to assess probability weighting functions	**DeCarlo:** Some Notes on Multivariate Signal Detection Models and Extensions	**Agrawal:** Cultural Consensus Theory: Estimating Consensus Graphs Under Constraints
10:20	***coffee break***		
10:45	**Bamber:** A Dutch Book Argument for the Situation-Specific Rationality of Non-Probablistic...	**Menneer:** Probit model and tetrachoric correlation approaches to GRT analysis	**Yu:** Probabilistic Models of Grounded Word Learning through Sensorimotor Child-Parent...
11:05	**Teodorescu:** Disentangling Models of Evidence Integration	**Thomas:** Beyond identification: Extensions of the GRT to paradigms with fewer responses than...	**Ramscar:** The Evolution Of Noun Classification In Two Germanic Languages
11:25	**Cassey:** Adaptive Sampling of Information During Perceptual Decision Problems	**Houpt:** General Recognition Theory Extended to Include Response Times: Predictions for a...	**Veloz:** A thought-mode dependent identification of context relevance and exemplar representativeness...
11:45	**Luhmann:** The Discriminability of Delay Discounting Models	**Townsend:** From Deep Space 9 to the Gamma Quadrant!	**Dye:** Information structure and the acquisition of numerical understanding
12:05	**Smith:** Assessing Consistency of Paired Comparisons in the Analytic Hierarchy Process		**November:** Simulating Word Learning for Continuous Stimuli via Prediction-Error
12:25	***lunch break (jmp meeting)***		
1:45	**Barbara Anne Dosher:** Changing the State of the Observer in Visual Processing		
2:45	***coffee break***		
3:10	**Dutilh:** Testing Theories of post-error slowing	**Golden:** Specification Testing using Eigenspectrum-Based Information Matrix Tests	**Bo:** Analyzing test-taking behavior: Prospect Theory meets Psychometric Theory
3:30	**Pan:** Revisiting visual-auditory integration in a redundant signal detection task	**Davis-Stober:** A New Perspective on Power and Replicability	**Verdonck:** The Ising Decision Maker: a thermodynamical approach to decision RT modeling
3:50	**Colonius:** Optimal time windows of audiovisual integration	**Houpt:** A Statistical Test for the Capacity Coefficient	**Rajendra:** Capturing the battle between ideas and ambiguities: A computational study on the...
4:10	**Diederich:** Testing saccadic reaction times to visual-auditory stimuli for oscillatory phase...	**Tang:** Computerized Adaptive Testing and Adaptive Experimental Design	**Commons:** Value and Stage Together May Predict Behavior
4:30		**Beaton:** Partial Least Squares-Correspondence Analysis (PLS-CA): A new approach to link measures...	**Stalne:** Application of the Model of Hierarchical Complexity to the derivation of Wave Equations...
5:00-6:30	***poster session***		

We ask that the last presenter in each session act as chair, and keep time for the session.

Time	Sunday, Distler	Sunday, Cohen	Sunday, Alumni
9:00	**Pizlo:** A necessary and sufficient condition for a 2D image to have a perceptually plausible...	**Province:** Recognition Memory is a Mixture of a Detect State and a Guess State	**Freund:** Separate Bayesian inference reveals model properties shared between multiple experimental...
9:20	**Perry:** A Test of Tri-Areal Matching Regularity for Two-Dimensional Stimuli	**Osth:** What are the Boundary Conditions of Differentiation in Episodic Memory?	**Schweickert:** Determining the Order of Mental Processes by Selectively Influencing Them
9:40	**Li:** Figure-ground organization from a single stereo image pair	**Dennis:** Context in the Wild	**Blaha:** The Proportional Reversed Hazard Rate Model Offers a Statistical Test of Workload...
10:00	**Abbott:** Applying a Bayesian measure of representativeness to sets of images	**Dunn:** State trace analysis of recognition memory	**Yang:** Multidimensional information processing: An extension of Systems Factorial Technology
10:20		***coffee break***	
10:45	**Dzhafarov:** Joint Distribution Criterion and Linear Feasibility Test for Selective Influences	**Criss:** Output Interference in Recognition Memory	**Tauber:** Evolutionary models of color categorization on networks
11:05	**Neufeld:** Analytic Construct Validity: Toward further Integration of Quantitative Cognitive...	**Starns:** RTCON and the Diffusion Model	**Zeigenfuse:** Modeling the Influence of Frequency and Discrimination on Associations Between Concepts...
11:25	**Steegen:** PSP based model selection	**Ratcliff:** Modeling Confidence and Response Time	**Canini:** Bayesian models for learning multiple related categories
11:45	**Van Paemel:** Theory testing with the prior predictive	**Shiffrin:** A Dynamic Activation Model for Accuracy and Response Time in Recognition Memory	**Nosofsky:** Categorization-Based and Recognition-Based Memory Scanning
12:05	**Verkuilen:** Model Comparison Is Judgment and Model Selection is Decision Making	**Cox:** Modeling Recognition of Different Stimulus Classes with a Dynamic Activation Model	**Rubin:** A Model of Generalization and Feature Representation Across Graph Hierarchies
12:25		***lunch break (smp meeting)***	
1:45		**Yann LeCun:** Training Hierarchical Systems for Visual Perception	
2:45		***coffee break***	
3:10	**Wiecki:** Fitting drift-diffusion models in a hierarchical Bayesian framework: methods and...	**Kellen:** Beyond ROCs: Fitting and extending recognition memory models with multiple-alternative,...	**Aitkin:** A Bayesian Model of Saccadic Timing
3:30	**Moscoso del Prado Martin:** The single-headed arrow of psychological time: The impossibility of linear autoregressive...	**Dunn:** Type 1 and Type 2 models of the mirror effect in recognition memory	**Matzke:** A Bayesian parametric approach for the estimation of stop-signal reaction time distributions
3:50	**Merlone:** Effort dynamics in supervised work groups with envious subordinates	**Chechile:** A Hazard and Reverse Hazard Examination of Recognition Memory Foils	**Petrov:** A novel method for the analysis of sequential eye movements
4:10	**Hidaka:** Information Theoretical Approach to Statistical Network in Bodily Actions	**Tang:** An Intuitive Method that Explores Structural Properties of Multinomial Processing...	**Vandekerckhove:** Numerical methods for fitting the Linear, Competitive Accumulator Model
4:30	**Greene:** Towards game theoretic analysis in large populations	**Denton:** Feature source confusion and discounting in both short-term priming and co-temporal...	**Van Maanen:** Single-trial Parameters in the Linear Ballistic Accumulator
5:00-6:30		***business meeting (followed by banquet)***	

We ask that the last presenter in each session act as chair, and keep time for the session.

Time	Monday, Distler	Monday, Cohen	Monday, East Sophia Gordon
9:00	**Turner:** Bayesian Analysis of Memory Models	**Trueblood:** Modeling Response Times in the Go/No-Go Discrimination Task	**Bicknell:** Empirical benchmarks for a rational model of eye movement control in reading
9:20	**Pooley:** Modeling Multitrial Free Recall when Rehearsals are Covert	**Chang:** The decision process of detecting changes in first- and second-order orientations	**Fischer-Baum:** Letter position representation in reading: An axiomatic analysis of the transposition...
9:40	**Donkin:** The structure of short-term memory scanning: An investigation using response time...	**Yang:** Relative change probability affects the decision process of detecting multiple feature...	**Adelman:** Letters in Time and Retinotopic Space: A model of letter position and identity extraction
10:00	**Fific:** Voluntary Control Over The Temporal Distribution Of Attention In Scanning Short Term...	**van Ravenzwaaij:** A new measure for post-error slowing: Robustness to global changes in task performance	**Purdy:** Coding Graphical Models: Probabilistic Context-Free Languages and the Minimum Description...
10:20		***coffee break***	
10:45	**Wyble:** Testing predictions of Event Related Potentials from the eSTST model supports a prior...	**Narens:** Alternative Probability Theory for Subjective Probability and Decision	**Osth:** What are the boundary conditions of differentiation? A test of the context shift...
11:05	**Manning:** Intracranial recordings yield novel insights into how episodic memories are represented,...	**Busemeyer:** Model Selection Applied to Quantum Probability Models	**Sreekumar:** The Dimensionality of Contexts
11:25	**Wenger:** Modeling the relationships between iron and behavior in the context of iron depletion...	**Dzhafarov:** Can We Do Without Sample Spaces?	**Yim:** The Development Of Context Use And Three Way Bindings In Episodic Memory
11:45	**van Vugt:** Between-trial effects in perceptual decision making - a model-based EEG analysis	**Kujala:** The Assumptions of Bayes' Theorem for Conditional Densities	**Collins:** Learning hidden structure for cognitive control
12:05	**Shankar:** A neural mechanism to represent the recent past		**Annis:** Modeling the Effect of Item Similarity on Sequential Dependencies in Recognition...
12:25		***lunch break***	
1:45	**Janne V. Kujala:** Dependence of random variables on external factors: Selectivity and adaptive estimation		
2:45		***coffee break***	
3:10	**Gosti:** Naming on a Directed Graph	**Zhang:** Optimal sequential sampling models for structured cue-based environments	**Love:** Feature Selection as Bayesian Model Comparison
3:30	**Negen:** A Thurstonian Model with Order Effects and Ties	**Wollschlaeger:** A random-walk model for multi-alternative preferential choice	**Kachergis:** An Associative Model of Inference in Statistical Word Learning
3:50	**Blokpoel:** A Computational-level Explanation of the Speed of Goal Inference	**Lee:** A self-regulating accumulator model of cue search	**Rafferty:** Faster Teaching by POMDP Planning
4:10	**Steyvers:** Dirichlet Process Mixture Models for Information Aggregation	**Hotaling:** Planning and Information Search in Multi-Stage Risky Decision Making	**Zhang:** Regularized Learning in Banach Spaces and Reference-Representational Biduality
4:30	**Noori:** Symbolic Simulation: a grounded mechanistic account for processing symbolic information		**Varona-Moya:** Grasping isomorphism: review of Hinton's "Learning distributed representations...
5:00-6:30		***end of meeting***	