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Book of Abstracts

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Scientific Committee:
Kujala Janne V.,
Albert Dietrich and
Colonius Hans

Technical editors Kujala Janne V.
Venäläinen Irene

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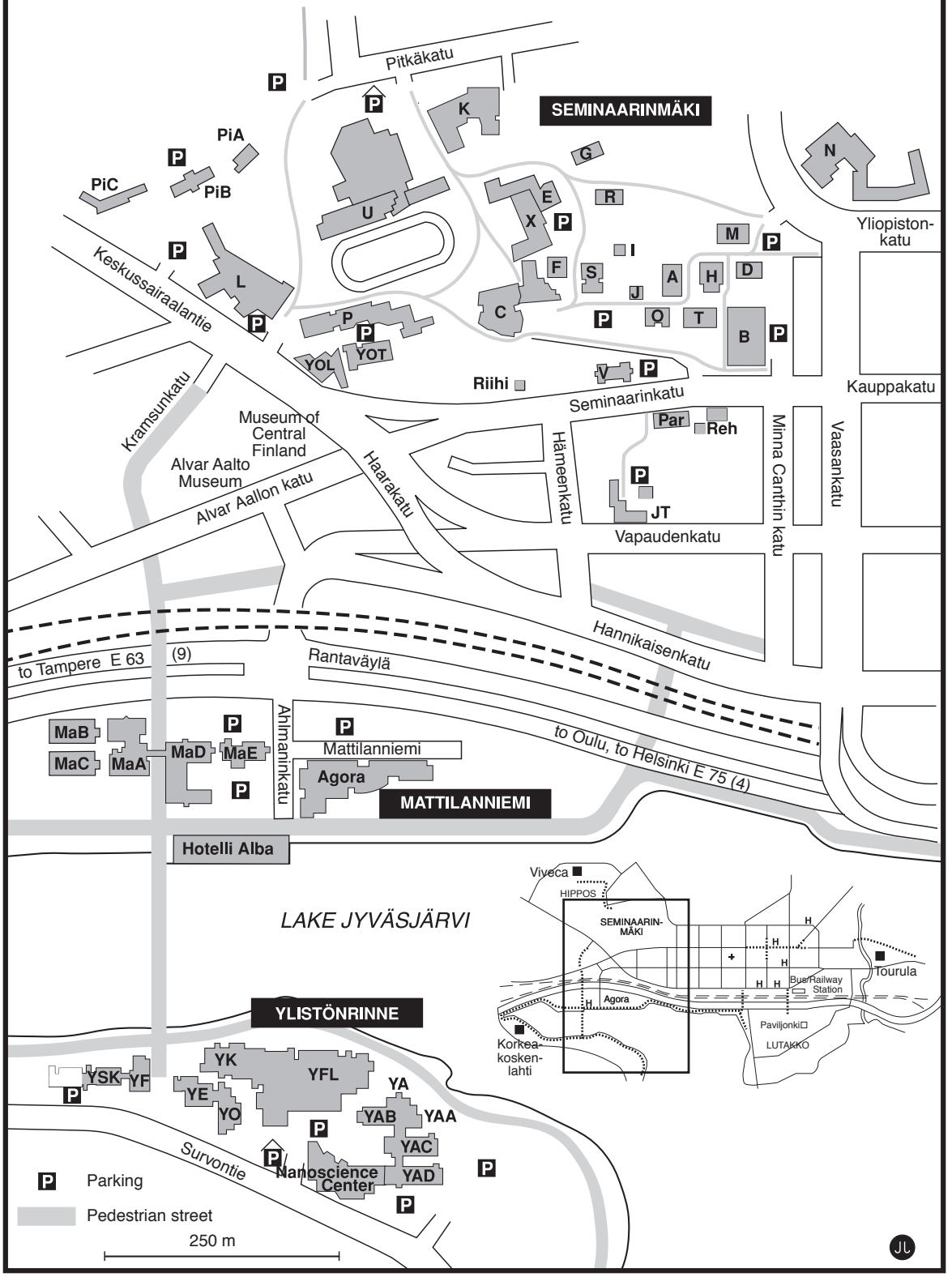

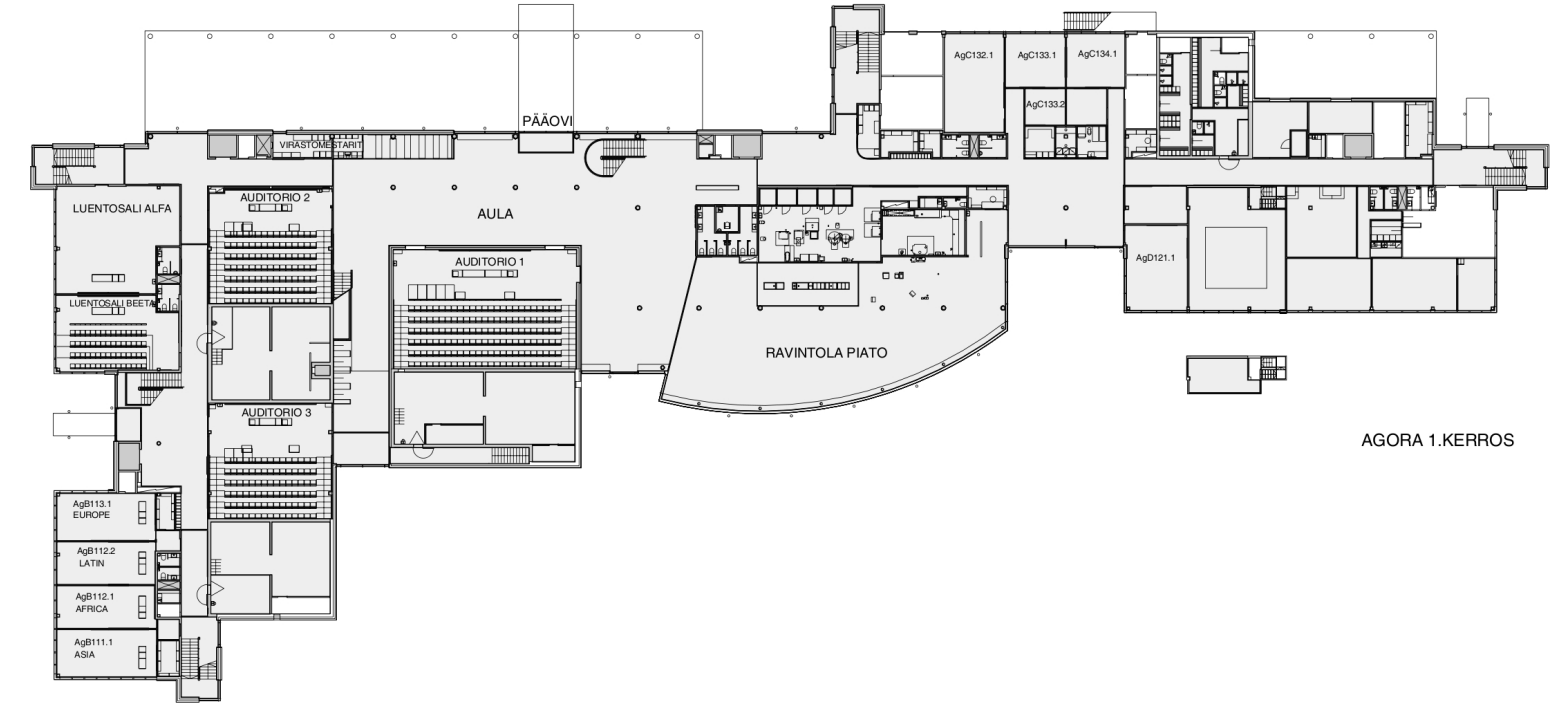

AGORA 1.KERROS

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General information

Get-together Party

The informal get-together party takes place at restaurant Alba on Sunday, August 29th, 19:00.

Registration

The registration desk is open during lecture hours at Agora 4th floor in front of Lea Pulkkinen hall starting at 8:00 on Monday August 30th.

Session and Lecture Rooms

Session and lecture rooms are located at the 1st and 4th floor of Agora building. See page 2 for Agora map. Lea Pulkkinen hall is located above Auditorium 3 in the 4th floor. Lecture room Beeta is at the first floor of Agora.

Uploading Presentation

Please upload your presentation before the beginning of your session. You are highly encouraged to test that all files will open properly. Please do not hesitate to ask for assistance from the registration desk if needed.

Internet Access

Free wireless internet access is available at Agora. You can also use the computer classes in the first and second floor of Agora. Please ask for a temporary user account at the registration.

Taxi

You can call a taxi from number +358 100 6900 (call fee 1.15 EUR). Pre-ordering a taxi more than 30 minutes beforehand costs 6.4 EUR extra.

Schedule

Sunday, 2010-08-29

18:00 - 21:00 **Informal get together party**

Monday, 2010-08-30

08:00 - 08:45 **Registration**

08:45 - 09:00 **Opening** *Lea Pulkkinen hall*

09:00 -10:00 **Invited lecture:** *Lea Pulkkinen hall*
Reinhard Suck: Psychometrics, Measurement Theory and Knowledge Spaces

10:00 - 10:30 **Coffee break**

10:30 - 12:30 **Knowledge space theory:** *Lea Pulkkinen hall*
Cord Hockemeyer: An Efficient Procedures for the Assessment of Competences
Pasquale Anselmi: A Log-Linear Reparametrization of the Gain-Loss Model
Item response theory:
Rocio Alcala-Quintana: Pros and Cons of RMSE and Other Indices in Item Response Theory
Jürgen Heller: Simultaneous Measurement of Persons and Items in Item Response Theory

12:30 - 14:00 **Lunch**

14:00 - 16:00 **2 Parallel sessions:**
Response times: *Lea Pulkkinen hall*
Matthias Gondan: Redundancy Gains in Simple, Go/Nogo, and Choice Reaction Time
Luca Stefanutti: A Discrimination-Association Race Model for the Analysis of the Implicit Association Test
Hans Colonius: Modeling Multisensory Integration: Optimal Time Window and Generalizations
Richard Shiffrin: Guided Visual Search
Computational linguistics: *Ag. Beeta*
Aleksi Keurulainen: A Bayesian Approach to Pronunciation by Analogy
Game theory:
Tatyana N. Savchenko: Developing a model for decision making in a game of two people with opposite interests
Nonparametric estimation:
Raffaello Seri: A Statistical Theory of Nonparametric Estimation in Economic and Psychophysical Experiments
Student modeling:
Rauli Ruohonen: Bayesian Student Modeling in a Learning Game: Or the factor analysis of stacks of biased coins

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

16:30 - 17:30 **Invited lecture:** *Lea Pulkkinen hall*

Jüri Allik

Posters (to be discussed on coffee breaks):

José Chacón: Orientation anisotropy in contrast shading perception

Debora de Chiusole: Probabilistic Knowledge Structure Models for Skill Dependence. An Application to the Assessment of Mathematical Skills in the Primary School

Yulia A. Chudina: Mechanisms of Visual Perception of Schematic Figures

Aire Raidvee: How Many Elementary Motion Signals are Counted in the Inference of Global Motion Direction?

Online paper:

Enrique Canessa: A Formal Model of the Spread and Demise of Concepts in Social Groups

Tuesday, 2010-08-31

09:00 - 10:00 **Invited lecture:** *Lea Pulkkinen hall*

Ehtibar Dzhafarov: Distance from Dissimilarity

10:00 - 10:30 **Coffee break**

10:30 - 12:30 **Scaling:** *Lea Pulkkinen hall*

Ragnar Steingrimsson: Theory of Common Psychophysical Ratio Scale of Intensity and Frequency Applied to Brightness and Hue

Lacey A. Perry: Matching Regularity for 2D Shapes and Locations

Chingis A. Izmailov: Integration of Simple Attributes of Stimulus in Neural Networks of Visual System

Irene Venäläinen: An Application of Fechnerian Scaling and Multidimensional Scaling to Confusion Probabilities of Finnish Letters

12:30 - 14:00 **Lunch**

14:00 - 15:30 **2 Parallel sessions:**

Judgment and decision: *Lea Pulkkinen hall*

Stéphane Deparis: Experimental Analysis of Incomplete Preferences

Justin MacDonald: The Signal Processing Approach to Human Classification, Part I: Empirical Data

J D Balakrishnan: The Signal Processing Approach to Human Classification, Part II: Dynamic Processes

Function estimation: *Ag. Beeta*

Richard Shiffrin: Causal explanations for Noisy Data: Function Estimation

Probabilistic causality

Ehtibar Dzhafarov: Selective Probabilistic Causality

Dynamic estimation:

Janne V. Kujala, Airi Kilpeläinen: Applying a Model of Learning to Sleep Deprivation Data

15:30 - 15:45 **Short coffee break**

15:45 - 16:45 **Invited lecture:** *Lea Pulkkinen hall*

Richard Shiffrin: Modeling the Coevolution of Event Memory and Knowledge

18:00 - 19:00 **Cruise on lake Päijänne from hotel Alba to Savutuvan Apaja**

19:00 - 22:00 **Conference dinner at Savutuvan Apaja**

(bus ride back to hotel Alba)

Wednesday, 2010-09-01

09:00 - 10:00	**Invited lecture:**	*Lea Pulkkinen hall*
	Peter Molenaar: Nonstandard applications of structural equation modeling	
10:00 - 10:30	**Coffee break**	
10:30 - 12:00	**Methodology and statistics:**	*Lea Pulkkinen hall*
	Miguel A. García-Pérez: Bayesian Adaptive Estimation of Psychometric Threshold and Slope: A Comparison of Methods	
	*Ingo Fründ:*Estimating Psychometric Functions in Nonstationary Observers	
	Jay Myung: Bayesian Adaptive Optimal Design for Discriminating Models of Cognition	
12:00 - 12:30	**Closing**	

Psychometrics, Measurement Theory and Knowledge Spaces

Reinhard Suck
University of Osnabrück
e-mail: rsuck@uos.de

A few general considerations concerning the nature and properties of a true measuring instrument are made. These will be applied to discuss physical measuring instruments, psychological tests in their classical form and in item response theory, and knowledge spaces. We shall set pointers concerning differences and similarities. We will try to describe the role of measurement theory in this discussion. Knowledge spaces are apparently a bit outside this development, in so far as their aim is to unveil the structure of a body of knowledge rather than to find numerical values. However assigning the knowledge state to a student in a given knowledge space has many features of a measuring process and it may be worth while to reconcile psychometrics with knowledge space theory. As it turns out well-graded infinite spaces are a useful tool in this enterprise.

Keywords: psychometrics, knowledge spaces, measurement theory, Dirac's δ function, Fourier transform, well-gradedness, set representations, saturation of set representations, item response theory.

An Efficient Procedures for the Assessment of Competences

Cord Hockemeyer
Department of Psychology
University of Graz
e-mail: cord.hockemeyer@uni–graz.at

Dietrich Albert
Department of Psychology
University of Graz

Thomas Augustin
Department of Psychology
University of Graz

Patrick Podbregar
Department of Psychology
University of Graz

Procedures for the assessment of knowledge have been a central aim in the development of knowledge space theory and its competence-based extensions. The mainly used approach to assessment is to estimate a probability distribution over the knowledge space and to update this probability distribution after each observed evidence. Recent applications in the field of game- and simulation-based learning, however, have uncovered certain weaknesses of this approach. The knowledge and competence structures in these areas grow quite large, such that a real–time behaviour of the assessment procedure as it is needed in games and simulations cannot be provided due to computational complexity. Furthermore, since competences from different areas are to be considered, the competence structures can easily get way too large to store the structure and the estimated probability distribution in the working memory of today's computers.

Recently, a new assessment procedure has been developed to answer the aforementioned challenges while trying to stay as close as possible to the functioning of the original algorithm. Some important properties with respect to model consistency have been proven. Simulation studies compare the new procedure with the original one considering computational efficiency as well as accuracy and testing efficiency on the other hand.

Keywords: Competence assessment, simulation, computational efficiency

A Log-Linear Reparametrization of the Gain-Loss Model

Pasquale Anselmi
Department of Applied Psychology
University of Padua
e-mail: pasquale.anselmi@unipd.it

Luca Stefanutti
Department of Applied Psychology
University of Padua
e-mail: luca.stefanutti@unipd.it

Egidio Robusto
Department of Applied Psychology
University of Padua
e-mail: egidio.robusto@unipd.it

The Gain-Loss Model (Robusto, Stefanutti, & Anselmi, in press) is a probabilistic skill multimap model (Doignon & Falmagne, 1999) for assessing learning processes developed in knowledge space theory framework. The gain and loss parameters assess the effect of learning objects on gaining and losing specific skills, respectively. These parameters are probability values indexed by learning object and skill.

To describe the learning process in more detail, a new reading is proposed that decomposes both gain and loss parameters into an effect of the skill, an effect of the learning object and an effect of their interaction. Log-linear modelling is used for this purpose.

An empirical application on the responses provided by university students to 12 problems in elementary probability theory is presented. Four skills were supposed to be required to solve the problems. A 2×2 experimental design with two learning objects (good and bad), and two assessment steps (pre-test and post-test) was planned. The bad learning object only presented the skill in mathematical terms, and it was given to a first group of students. The good learning presented both the skill in mathematical terms and an application example, and it was given to a second group of students.

Results of the empirical application are presented, and usefulness of the new parameters for describing the learning process is discussed.

Keywords: Learning object, learning process, log-linear model, knowledge space theory

References:

Doignon, J.-P., & Falmagne, J.-C. (Eds.). (1999). *Knowledge spaces*. Berlin, Germany: Springer-Verlag.

Robusto, E., Stefanutti, L., & Anselmi, P. (in press). The Gain-Loss Model: A Probabilistic Skill Multimap Model for Assessing Learning Processes. *Journal of Educational Measurement*.

Pros and Cons of RMSE and Other Indices in Item Response Theory

Rocio Alcala-Quintana
Departamento de Metodologia
Facultad de Psicologia
Universidad Complutense
e-mail: ralcala@psi.ucm.es

Miguel A. Garcia-Perez
Departamento de Metodologia
Facultad de Psicologia
Universidad Complutense
e-mail: miguel@psi.ucm.es

A universally accepted index to compare the efficacy of various methods and procedures in Item Response Theory (IRT) is the root mean square error (RMSE). Yet, RMSE has recently been shown to be misleading when the two set of magnitudes to be compared (typically a sample of estimates of some parameters and the corresponding true values) differ in metric. Metric differences are a usual, and otherwise inconsequential, side effect of estimation procedures in IRT. The problem arises because RMSE measures scatter around the identity line, not just around whichever line (or curve) the data might actually follow as a result of metric differences. Then, judging as most efficacious the procedure which yields the lowest RMSE frequently leads to incorrect conclusions. In this study we seek a dependable alternative to RMSE. The pros and cons of various alternative indices are investigated in a simulation study where item parameters were generated and estimated under several IRT models (both dichotomous and polytomous). Indices evaluated included RMSE, the product-moment correlation coefficient between true and estimated parameters, the concordance correlation coefficient, and the standard deviation of regression residuals. Since metric differences become readily apparent when scatterplots are inspected, they were used as a criterion. Preliminary results reveal that only the product-moment correlation and the standard deviation of regression residuals are not affected by metric differences, which are often quasi-linear, but any conclusion on efficacy must also be based on the visual inspection of scatterplots.

Keywords: RMSE, IRT, Metric differences

Simultaneous Measurement of Persons and Items in Item Response Theory

Juergen Heller
Psychological Institute
University of Tuebingen
e-mail: juergen.heller@uni-tuebingen.de

Even 50 years after Georg Rasch suggested a psychometric model that now carries his name there is still a debate on the scale type of the measurements of persons and items it establishes. On the basis of the formal theory of scales (Narens, 2002) it is shown that Fischer's (1995) claim, that the Rasch model provides interval scale measurements, is wrong. His argument is flawed, as he fails to properly distinguish between the admissible transformations of the representation on the one hand, and reparametrizations of the model on the other hand. Besides clarifying the scale type of the Rasch model we also discuss the role of solvability assumptions (i.e. assumptions on the richness of the sets of persons and items) for its uniqueness, as well as that of less restrictive ordinal and conjoint representations. Particular emphasis is on simultaneously measuring persons and items on a common scale.

Keywords: Latent trait theory, measurement theory, scale type, model reparametrizations

Redundancy Gains in Simple, Go/Nogo, and Choice Reaction Time

Matthias Gondan
Department of Psychology
University of Regensburg
e-mail: matthias.gondan@psychologie.uni-regensburg.de

Steven P. Blurton
Department of Psychology
University of Regensburg
e-mail: steven.blurton@psychologie.uni-regensburg.de

In divided attention tasks with two classes of target stimuli, participants typically respond faster if both targets are presented simultaneously, compared to single target presentation (redundant signals effect, Miller, 1982, Cognit Psychol). Different explanations exist for this effect, including serial, parallel, and coactivation models of information processing. For models which assume separate activation of the two channels, Miller demonstrated that redundancy gains have an upper limit (race model inequality),

$$F_{AV}(t) \leq F_A(t) + F_V(t), \text{for all } t.$$

In simple reaction time tasks this limit is often exceeded, suggesting integrated processing of bimodal information. The diffusion superposition model (Schwarz, 1994, J Math Psychol) is an important member of the alternative class of coactivation models. Upon presentation of stimulus, build-up of sensory evidence is described by a time-homogeneous diffusion process with drift μ and variance σ^2. Detection occurs when a criterion c is passed for the first time. In bimodal stimuli, the sensory-specific processes overlap. For independent channel specific processes, this results in an aggregate process with drift $\mu_A + \mu_V$ and variance $\sigma_A^2 + \sigma_V^2$. Due to the increased drift rate, the criterion c is reached earlier in redundant stimuli than in unimodal stimuli.

In a series of experiments we investigated redundancy gains in simple reaction times and in more complex tasks (Go/Nogo, choice reaction time) for auditory-visual stimuli presented with an onset asynchrony. In Experiment 1, Go/Nogo discrimination was performed for near-threshold and suprathreshold stimuli. Response times in both the simple and Go/Nogo responses were well explained by a common diffusion model assuming linear superposition of modality-specific activation.

In Experiment 2, the Go/Nogo task was made more difficult. Participants had to respond to high frequency tones or right-tilted Gabor patches, and to withhold their response for low tones and left-tilted Gabors. Redundancy gains were again consistent with coactivation models. Response times of one participant, however, support a serial self-terminating model of modality-specific information processing. It turns out that serial self-terminating processing can be mimicked by a special case of the diffusion superposition model.

In Experiment 3, participants had to make choice responses to audiovisual stimuli. The results favour again coactivation accounts, with identical elementary perceptual processes, but task specific response execution. Our results emphasize the potential of additive neural integration mechanisms to explain behaviour in complex tasks.

Keywords: Response time, Redundant Signals Effect, Diffusion Model

A Discrimination-Association Race Model for the Analysis of the Implicit Association Test

Luca Stefanutti
Department of Applied Psychology
University of Padua
e-mail: luca.stefanutti@unipd.it

Egidio Robusto
Department of Applied Psychology
University of Padua
e-mail: egidio.robusto@unipd.it

Michelangelo Vianello
Department of Applied Psychology
University of Padua
e-mail: michelangelo.vianello@unipd.it

Pasquale Anselmi
Department of Applied Psychology
University of Padua
e-mail: pasquale.anselmi@unipd.it

The Implicit Association Test (IAT) is a computerized procedure that assesses the relative strength of the associations between two target categories (e.g., "flowers" and "insects") and two attribute categories (e.g., "positive" and "negative"). Stimuli representing each category have to be categorized by pressing, as quickly and accurately as possible, one of two response keys. In test blocks, target and attribute categories are mapped onto the same response keys in different combinations.

A discrimination-association race model for the analysis of the IAT is presented. Discrimination regards the amount of information that a target (attribute) stimulus contains for the target (attribute) categories. Association regards the amount of information that a target (attribute) stimulus contains concerning an attribute (target) category. Four parallel and independent Poisson processes, each of which concerns a specific category, have been considered. Information about a specific characteristic of stimuli accumulates on the counter of each process until a termination criterion is reached and a response is given. Speeds of information accumulation vary with processes and stimuli. Termination criteria vary with blocks, stimulus categories and response categories (correct and incorrect). The model takes into account both latency and accuracy of the responses. The latency is determined by the time at which a process wins. The accuracy depends on the winning process, the category of the displayed stimulus, and the test block.

In an empirical application, parameter estimates and goodness-of-fit were computed for each of one-hundred respondents to a Conscientiousness-IAT. Practical implications of the model for understanding the IAT measure are discussed. In particular, it is shown that, for each respondent, the speed-accuracy task can be decomposed into four components: the discriminability of the stimuli (discrimination), the association of stimuli to categories (stimulus-driven target/attribute association), the association of categories to stimuli (category-driven target/attribute association), and the difficulty of different blocks involved in the procedure (termination criteria). Advantages and disadvantages of the model are considered in comparison to other models for the analysis of the IAT.

Keywords: Race model, Poisson process, Implicit Association Test, implicit measures

Modeling Multisensory Integration: Optimal Time Window and Generalizations

Hans Colonius
Department of Psychology
University of Oldenburg
e-mail: hans.colonius@uni-oldenburg.de

Adele Diederich
School of Humanities and Social Sciences
Jacobs University Bremen
e-mail: a.diederich@jacobs-university.de

The spatiotemporal window of integration has become a widely accepted concept in multisensory research: crossmodal information falling within this window is highly likely to be integrated, whereas information falling outside is not. Making explicit assumptions about the arrival time difference between peripheral sensory processing times triggered by a crossmodal stimulus set, we have derived a decision rule in a reaction time context that determines an optimal window width as a function of (i) the prior odds in favor of a common multisensory source, (ii) the likelihood of arrival time differences, and (iii) the payoff for making correct or wrong decisions (Colonius & Diederich, 2010, *Frontiers in Integrative Neuroscience*).

Here we discuss possible variants of the theory including the focused attention paradigm where subjects are instructed to only respond to stimuli from a target modality and to ignore stimuli from another, non-target modality. Moreover, we discuss generalized versions of the time window of integration (TWIN) model based on order statistics, and consider possible empirical tests.

Keywords: Multisensory integration, optimal time window, order statistics

Guided Visual Search

Chris Donkin
Indiana University

Denis Cousineau
University of Montreal

Richard Shiffrin
Indiana University
e-mail: shiffrin@indiana.edu

Cousineau and Shiffrin (2004) presented a model for the control conditions of a visual search study. Multiple modes were observed for target present trials and the model posited serial terminating comparisons, partially and probabilistically guided to the target location by a separate parallel automatic process. We expand and extend this model to fit the distributions of response times for the control conditions and also the experimental conditions in which the visual display objects are presented successively, at speeds fast enough that the displays appear simultaneous. The distributions and the results from the successive display conditions place strong constraints on models, and allow us to develop a quite precise account for parallel and serial processes operating together in visual search.

A Bayesian Approach to Pronunciation by Analogy

Aleksi Keurulainen
Department of Mathematical Information Technology
University of Jyväskylä
e-mail: lxi@iki.fi

Janne V. Kujala
Agora Center
University of Jyväskylä
e-mail: jvk@iki.fi

Pronunciation by analogy (PbA) is a data-driven method of constructing pronunciations for unknown words. Pronunciations are constructed by segmenting an unknown word into substrings and matching these substrings to those of known words, and then combining the pronunciations of the matched substrings to form a pronunciation for the whole word. The candidate pronunciations are ranked with heuristically justified evaluation methods and the best-performing candidate is selected.

In this paper, instead of applying heuristic evaluation rules, we present a simple Bayesian formulation of the problem. An input word is considered as a string of letters with 'space' characters indicating its beginning and end. Each segmentation of the word into previosly seen substrings with a minimal number of segments is considered as a potential model of the possible pronuncations of the word. Given a segmentation, each segment in it has a probability distribution of different pronunciations according to the frequencies of these pronunciations in the instances where the segment in question appears in known words. The product of the probability distributions of all segments of a segmentation yields a distribution of whole-word pronunciations. We assume that a priori each segmentation has the same probability of being the correct generating model and given this, we choose the whole-word pronunciation that has the highest probability of being the correct one. These computations turn out to be similar, but different in certain details from any previously suggested evaluation rules.

Tests done on dictionary data from NETtalk ($N = 19595$) show that this simple formulation outperforms any single evaluation rule used previously.

Keywords: Pronunciation by analogy (PbA), Bayesian statistics

Developing a model for decision making in a game of two people with opposite interests

Tatyana N. Savchenko
Institute of psychology RAS
e-mail: msavch@psychol.ras.ru

Galina M. Golovina
Institute of psychology RAS
e-mail: gala-galarina@mail.ru

In this paper we tried to experimentally analyze the behavior of players in non-adversarial game with the aim of constructing a mathematical model of such behavior, taking into account individual characteristics of players. J. von Neumann has proved to play two-person nonzero-sum existence of such mixed strategies that maximize the guaranteed payoff of each player.

In experiments with specific games, two individuals showed that the players used different criteria. For example: 1) maximize his winnings, and 2) minimizing the winning partner, and 3) maximize winning partner, etc. All these examples of criteria are described in terms of maximizing or minimizing each player is given a linear combination of wins (and their partner) with fixed (its: for each player) coefficients of the linear combination.

The criterion (a goal that seeks to achieve this player) is defined as the maximization or minimization of a given linear combination of winning. The game is supposed beskoalitsionnoy, each player chooses his strategy independently. Solution of a game in this case - a lot of mixed strategies of all players who meet the criteria selected by each of the players. Thus, the definition of solution of the game, given us is a generalization of the concept of solution of the game proposed by Dzh.fon Neumann. The paper discusses specific examples of games and benchmarks for the game, two people with opposite interests. For games such as "family dispute" and "prisoner's dilemma", the new method obtained all the solutions found previously, and a large number of new solutions for pairs of criteria, not considered previously.

Subject to conflict often do not behave according to the rules proposed by the regulatory model of the classical theory of games (in some cases, irrational), but relies on its own criteria, which can profit vary. Depending on the individual characteristics and situation of each participant formed a criterion of its behavior in the proposed situation. We solve the system of inequalities, are the area that meet the criteria of the first party, which determine the solution of the game for a given matrix. Further, the same procedure is carried out for the second player. The space of mixed strategies, which is the intersection of spaces of both players, which is the solution of the game.

Thus knowing the criteria and the matrix gains can be determined whether under these criteria to find solutions from the existing range, satisfying the criteria of both players and the matrices have been reported. If the set of solutions do not have intersections, then the solution does not exist. We have developed a computer program for constructing the spaces of the expectations for the various matrices winnings. To verify the adequacy of the model we have developed a paired experiment.

A Statistical Theory of Nonparametric Estimation in Economic and Psychophysical Experiments

Michele Bernasconi
Dipartimento di Scienze Economiche
Università di Venezia
e-mail: bernasconi@unive.it

Raffaello Seri
Dipartimento di Economia
Università dell'Insubria
e-mail: raffaello.seri@uninsubria.it

Christine Choirat
Department of Quantitative Methods, School of Economics and Business Management
Universidad de Navarra
e-mail: cchoirat@unav.es

The aim of this paper is to provide a statistical foundation for a nonparametric method of analysis suitable for economic and psychophysical experiments. Consider a quantity depending on some primitive quantities through an unknown function f (such as the certain equivalent as a function of the probabilities and the payments in a lottery). f can be studied in an experiment in which J subjects are gathered, the same I questions are proposed to each individual and he/she provides a set of I responses. This rises the point whether a large number of individuals or of questions is better for the design of an economic experiment. The function f is estimated nonparametrically through f_P, a linear combination of a set of P basis functions (power series, regression splines, trigonometric functions, etc.); we suppose that, when $P \to \infty$, the set of basis functions describes accurately the function f. The weights in the function f_P can be estimated through linear regression supposing independence between individuals and answers across individuals. Estimators are consistent when J and I diverge to infinity, even if the answers of an individual are correlated and if this correlation is different across individuals. The rate of convergence of the estimated f_P to f depends upon J, I, the covariance structure of errors across individuals and the degree of approximability of f through a set of basis functions (i.e. the smoothness of f); a convergence rate is also obtained for derivatives. We consider in detail the case in which f is estimated nonparametrically through power series or regression splines. We derive the optimal divergence rate of P with both I and J and choose the optimal balance between I and J. It turns out that in general a large value of J is better than a large value of I. Conditions for asymptotic normality of linear and nonlinear functionals of the estimated function of interest are derived. This is used to derive the asymptotic distribution of Wald tests when the number of constraints under test is finite (a chi-squared distribution) and when it diverges to infinity (a normal distribution), and the distribution of LR tests of linear constraints. We provide bounds on the error of the approximation. Lastly, we investigate what happens when the average variance matrix appearing in the previous tests is replaced by an estimator, and consider nonparametric estimation of the conditional variance.

Keywords: nonparametric estimation, psychophysics, experimental economics

Bayesian Student Modeling in a Learning Game: Or the factor analysis of stacks of biased coins

Rauli Ruohonen
Agora Center
University of Jyväskylä
e-mail: rauli.ruohonen@gmail.com

Janne V. Kujala
Agora Center
University of Jyväskylä
e-mail: jvk@iki.fi

The possibility of early identification of dyslexia has motivated the development of the computer game "Literate", which is designed for the early prevention of reading difficulties. It is important that the learning content in the game is adapted for individual players so that the game will be neither too difficult nor too easy. For this purpose, it is helpful to have a precisely defined statistical model of the player.

In this paper, we present a Bayesian model of the player. The model can be used for the selection of effective game content and for tracking the players' progress. The model is essentially a combination of factor analysis and the logistic model.

In the game, the players are presented with choice situations, where letters of the alphabet are displayed on the screen. The task is to select the letter that corresponds to the sound that is played at the same time. Information about the choice situations and the choices the players make is stored in game logs, which we use to fit the model. We are basically performing a factor analysis on the skills of the players, which are observable only through the choices the players make.

There are three pre-existing statistical player models for Literate, but in all of them only one player is taken into account at a time, independently of all the other players. In contrast, in the model proposed in this paper all the players are considered simultaneously, allowing the model to learn statistical properties of the player population. The pre-existing model best suited for the analysis of the game data is used to construct baseline models in this paper.

The employed model and fitting method are tested using simple simulations as well as real game log data. The model works well in the simulations, if there is enough data for each player. The model also predicts player choices in the real data better than the baseline models.

Keywords: factor analysis, logistic model, Laplace approximation, Luce's choice axiom, Bayesian statistics, machine learning, learning game

Orientation anisotropy in contrast shading perception

J. Chacón
Metodología de las CC. CC.
Universidad Complutense
e-mail: jchacon@psi.ucm.es

M. A. Castellanos
Metodología de las CC. CC.
Universidad Complutense
e-mail: mcastellanos@psi.ucm.es

I. Serrano-Pedraza
Institute of Neuroscience
Newcastle University
e-mail: i.s.pedraza@ncl.ac.uk

Shading is a major source of information for acquiring knowledge about the shape of objects. Among other aspects related to shading perception, previous work has shown that certain kind of shaded stimuli (with 3D interpretation) are perceived with different contrast depending on the polarity of their dark and light areas. In particular, circles filled out with a top-dark luminance ramp were perceived as having greater contrast than top-light circles, although both types of stimuli had the same physical contrast. This has been related to certain asymmetries reported in studies on visual search tasks.

In this work we study how shading orientation affects the perceived contrast.

We measured the perceived contrast using an adaptive spatial two-alternative forced-choice procedure in which subjects were presented with two horizontally-arranged set of stimuli and they had to indicate which set (either left or right) had higher contrast. The contrast of the standard stimuli was kept constant whereas the contrast of the test stimuli was manipulated with an adaptive staircase to estimate the point of subjective equality. Stimuli consist of circular patches gilled with luminance ramps of different orientations (from -90 deg to 90 deg in steps of 22.5 deg, where vertical corresponds to 0 deg), yielding nine experimental conditions.

Our results show strong orientation anisotropy in shading perception. In particular:

1. Vertical luminance ramps produce greater differences in perceived contrast between top-dark and top-bright circles, compared to circles with horizontal luminance ramps.

2. The maximum difference in perceived contrast does not coincide with vertical (0 deg) luminance ramps, but it is deviated to the left about 14 deg.

Both outcomes are consistent with those reported in other studies (visual-search tasks and 3D rating).

Keywords: shading, contrast perception, anisotropy, shading orientation

Probabilistic Knowledge Structure Models for Skill Dependence. An Application to the Assessment of Mathematical Skills in the Primary School

Debora de Chiusole
Dipartimento Di Psicologia Applicata
Universita' Degli Studi Di Padova
e-mail: deboratn@libero.it

Luca Stefanutti
Dipartimento Di Psicologia Applicata
Universita' Degli Studi Di Padova
e-mail: luca.stefanutti@unipd.it

A probabilistic knowledge structure model for skill dependence and multiple solution strategies is presented. An application of the model to the assessment of mathematical skills in the primary school is illustrated and discussed.

At an algebraic (deterministic) level the model is specified through the two concepts of a *skill structure* (sometimes called a *competence structure*) and a *skill multi-map*.

The former is a collection of subsets of a suitable set S of skills, whose aim is to provide an algebraic representation of the dependence among the skills. The latter is a mapping from an appropriate collection of problems (or items) Q to nonempty collections of nonempty and pairwise incomparable subsets of skills. Each of the subsets of skills assigned to a given problem in $q \in Q$ is meant to be a specific solution strategy for q in the sense that it contains necessary and sufficient skills for a successful solution of the problem.

At a probabilistic level the model assumes a probability distribution on the subsets (or skill states) in the skill structure. Concerning conditional independence of the skills, specific assumptions of the model assure a correspondence between the algebraic and the probabilistic representation, so that the dependence/independence of the skills can be directly read off the graph of a skill structure.

The results of an application of the model to the assessment of the mathematical skills of 399 children in the 3rd grade of the Italian primary school are illustrated and discussed.

In particular it will be shown how, on the basis of an initial model specifying the skills and strategies underlying the problems, new strategies can be discovered using post-hoc analyses of the model parameters, and then tested against the empirical data.

Furthermore it will also be shown how the skill dependence framework allows to specify and test the presence of ordinal skills. In this respect an emblematic example is the presence of one or more carries (respectively, borrowings) in written addition (resp., subtraction) problems, as well as their proximity.

The results suggest that, with children in the 3rd grade, the number of carries plays a minor role in addition, while the number of borrowings plays a major role in subtraction problems. Moreover proximity of carries plays no role in addition but proximity of borrowings has a strong impact in subtraction problems.

Keywords: knowledge structures, mathematical skill assessment in children, probabilistic models, skill dependence

Mechanisms of Visual Perception of Schematic Figures

Yulia A. Chudina
Department of Social and Differential Psychology
Peoples Friendship University of Russia
e-mail: renyxa4@yandex.ru

The visual perception of environment objects is achieved by mean of two functions of visual system. On the one hand the visual system analyzes pattern recognition, and on the other hand it carries out form perception of an object. The first function provides detection of outer border, separation of a figure from a background, one-by-one specifications of internal structure of the image etc. The second function appears in forming of the complete object image which depends on visual experience and object accessory to some class or category.

In the present work these functions of visual system were studied. The same stimuli (schematic pattern of the watch dial) were presented to two groups of subjects and were accompanied by two different instructions. The first group of subjects estimated distinctions between the stimuli described like batch of lines with different orientation. The second group of subjects estimated distinctions between clock dials with various values of time. In the issue we have built the configurative and categorial space. They were constructed by estimations multidimensional scaling of dissimilarities between the stimuli for each group of subjects separately. The ready-built spaces were analyzed in terms of dual-channel spherical model of stimuli discrimination (Izmailov, Sokolov, 1991). It has been shown that the configurative dissimilarities give three-dimensional Euclidean space in which stimuli-points are located on the sphere surface. Two spherical coordinates of points were interpreted as two features of the pattern of stimuli: the angle between lines-arrows and orientation of its bisector. The three-channel neural network has been constructed as combination of two dual-channel models: distinctions between angles (Izmailov, Sokolov, 1990) and line orientations (Izmailov, Chudina et al. 2004). At the same time two-dimensional Euclidean space has been obtained for estimations of time dissimilarities in which stimuli-points are located on the circle.

Thus, the visual system carries out, at least, two functions. One function consists in pattern analysis, and another is connected with a categorization of the familiar objects. These two different functions are started by one stimulus (accompanied two different instructions) and have no direct connection. However, we suppose that between them there is artificial relationship created in process of training.

Keywords: form perception, distinctions estimation, schematic figures, multidimensional scaling, detectors of features, dual-channel neural network, visual categorization.

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How Many Elementary Motion Signals are Counted in the Inference of Global Motion Direction?

Aire Raidvee
Institute of Psychology
University of Tartu
e-mail: aire.raidvee@ut.ee

Kristiina Averin
Institute of Psychology
University of Tartu

Kairi Kreegipuu
Institute of Psychology
University of Tartu

Jüri Allik
Institute of Psychology
University of Tartu

Currently, knowledge about the efficacy of local motion information pooling on global direction perception is rather limited. Assumption made by most studies – that at least the majority of local motion signals are used in the processing of global motion direction – has as yet remained unproven. Ideal observer analysis has been a method of choice in estimating human efficiencies in motion detection and discrimination tasks. Previous applications of the ideal observer methodology to the pooling of elementary motion signals have used rather complex random dot motion displays requiring rather elaborate assumptions about the ideal decision mechanism. The main purpose of our study is to simplify motion displays to the degree in which the application of the ideal observer analysis would imply as few postulated assumptions as possible.

In our experiment, the observers' task was to indicate in which of two opposite directions, to the right or to the left, an entire display appeared to move, based on the proportion of rightward or leftward motion elements, each of which was distinctly visible. The performance of each observer was compared with a counting device which measured a randomly selected subsample of all available motion elements.

Surprisingly, decisions about the global motion direction made by all six observers were based on counting very few elements. Regardless of how many motion elements the participant saw in a range of 12 to 800, global motion perception was based, on average, by taking into account 4 $\pm$ 2 random moving dot elements. It is therefore concluded – counter to commonly held belief – that the motion pooling mechanism studied in this experiment is severely limited in capacity and therefore cannot be considered to be entirely parallel, effortless, or automatic.

Keywords: random dot kinematograms, motion pooling, global motion direction, statistical efficiency, capacity limitation, effortless perception

Distance from Dissimilarity

Ehtibar N. Dzhafarov
Purdue University

I will discuss formal properties of the notion of dissimilarity and the computation of distances by means of Dissimilarity Cumulation (DC). On nite stimulus spaces (e.g., data sets), DC can be viewed as a procedure recursively making minimal cor- rections in the values of dissimilarities which are necessary to eliminate violations of triangle inequality. DC followed by metric Multidimensional Scaling (MDS) provides an alternative to nonmetric MDS. One empirical nding is that the scree plots (stress vs number of dimensions) produced by DC with metric MDS usually exhibit much sharper elbows (i.e., more denitively indicate the optimal number of dimensions) than the scree plots produced by nonmetric MDS. I will also discuss the computation of dissimilarities from discrimination functions. In this context the central notion is that of Regular Minimality (RM). I will show how one can dene a number of violations of RM in a matrix, and I will introduce a permutation test for RM based on this denition.

Theory of Common Psychophysical Ratio Scale of Intensity and Frequency Applied to Brightness and Hue

Ragnar Steingrimsson
Institute for Mathematical Behavioral Sciences
University of California, Irvine
e-mail: ragnar@uci.edu

Louis Narens
Institute for Mathematical Behavioral Sciences
University of California, Irvine
e-mail: lnarens@uci.edu

R. Duncan Luce
Institute for Mathematical Behavioral Sciences
University of California, Irvine
e-mail: rdluce@uci.edu

Extending results of Narens (1996), Luce (2002, 2004) proposed a theory of global psychophysics in which a simple representation derives from directly testable behavioral properties. These properties have, in fact, been extensively tested and sustained in the contexts of loudness of pure tones and of brightness of achromatic lights. Using the methods of magnitude estimation and production, these results establish the ratio scalability of measurements scales for these domains at a fixed pitch and fixed hue. These results lead to the question: What relation does the ratio property have for different frequencies; is there a common representation or very distinct ones? The heart of Narens' (2006) result is that when a subjective intensity scale forms a ratio scale at fixed frequency, then a certain commutative property must hold. Luce, Steingrimsson, and Narens (in press) extended that theory to loudness at different frequencies (pitch), and that too was positively evaluated showing that an individual can be said to have a common ratio scale of loudness for different frequencies. Recently, we have adapted the theory to ask the same question for brightness across different frequencies (hues). Preliminary results support the existence of a common scale for brightness of different hues. The underlying theory and a full set of empirical results will be reported. Should the preliminary results be sustained, they represent a novel common description of two domains that leads to several intriguing questions: Is there a common subjective intensity over the two modalities? Should that be sustained, to which modalities does it extend? Is there simply a single ratio scale of subjective intensity over all of what S. S. Stevens called prothetic continua?

Keywords: Measurement theory, scaling, psychophysics, brightness, hue, color.

Matching Regularity for 2D Shapes and Locations

Lacey A. Perry
Purdue University
e-mail: laperry@purdue.edu

Ehtibar N. Dzhafarov
Purdue University
e-mail: ehtibar@purdue.edu

The general definition of well-matched regular stimulus spaces is given in Dzhafarov & Dzhafarov (2010, *Theoria*, 76, 25-53). When applied to pairwise presentation of stimuli in two fixed observation areas (e.g., one on the left, one on the right), the notion implies that (1) for every stimulus x one can find a stimulus y in another observation area such that x and y match each other; and (2) if an x matches both y and y, then y and y are equivalent (in the sense of always matching or not matching any stimulus together). This property has nontrivial consequences for several issues, ranging from the ancient sorites paradox to modeling of discrimination by means of Thurstonian-type models. We have tested the regular well-matchedness hypothesis for locations of two dots within two side-by-side circles, and for two side-by-side flower-like shapes, each described by $R + K_a\, cosa\theta + K_b\, cosb\theta$ in polar coordinates. In the location experiment the coordinates of the dot in one circle were adjusted to match the location of the dot in another circle. In the shape experiment the amplitudes K_a, K_b of one shape were adjusted to match the other shape. The adjustments on the left and on the right alternated in long series according to the ping-pong matching scheme developed in Dzhafarov (2006, *Journal of Mathematical Psychology*, 50, 74-93). The statistics of the adjustment series have been found to be in a good compliance with the regular well-matchedness hypothesis.

Integration of Simple Attributes of Stimulus in Neural Networks of Visual System

Ch. A. Izmailov
Department of Psychology
Moscow State University
e-mail: ch_izmailov@mail.ru

E. N. Sokolov
Department of Psychology
Moscow State University

I. V. Edrenkin
Department of Psychology
Moscow State University
e-mail: ilya.edrenkin@gmail.com

We propose for visual detection of complex, multidimensional stimuli a geometric representation reflecting a modularly organized neural network. We used figures designated as "arrows", "forks" and "T-shapes," all formed by three lines meeting at a common vertex. Each of these three types of figures represented a simple, one-dimensional set of stimuli, as due to their symmetry they are characterized by a single angular parameter. As a result of multidimensional scaling of pairwise dissimilarity estimates of these three-line figures, it has been shown that the figures within each of the three types can be represented by points on a circle in two-dimensional Euclidean space. This accords with the geometrical model that has been obtained previously for other one-dimensional figures, for example, two-line figures with varying angle. Such a geometric representation — a spherical model of discrimination — allows one to consider the visual mechanism of distinguishing figures of a given type as a two-channel neural network, a basic module of visual system. Let the two channels for the "arrows" be denoted A1-A2, with F1-F2, and T1-T2 defined analogously for "forks" and "T-shapes." It has been shown that the three two-channel neural networks form an integrated neural network representing all three types of three-lines figures. This integrated network consists of three channels, I1-I2-I3, such that A1, F1, and T1 activate I1, while A2, F2, and T2 contribute to both I2 and I3. Of these I2 has the same function as A2, F2, and T2, while I3, possibly, specifies the type of the three-line figures.

Keywords: geometric shapes, modular organization, multidimensional scaling, spherical model

An Application of Fechnerian Scaling and Multidimensional Scaling to Confusion Probabilities of Finnish Letters

Irene Venäläinen
Agora Center
University of Jyväskylä
e-mail: iiki@iki.fi

Janne V. Kujala
Agora Center
University of Jyväskylä
e-mail: jvk@iki.fi

Literate (Ekapeli) is a learning game, the initial goal of which is to teach the player to associate letters to their speech sounds. In the Finnish language, these connections are practically 100% consistent, that is, each letter has its own sound and each sound has its own letter. The game consists of multiple-choice trials containing visually presented letters and a speech sound; the player's task is to choose the letter corresponding to the sound heard.

In this work, we use the data from Kujala, Richardson, and Lyytinen (Estimation and visualization of confusability matrices from adaptive measurement data. *Journal of Mathematical Psychology*, 54(1);196–207, 2010) containing probabilities of the correct answer for each letter–sound pair gathered from all the players ($N = 2600$) of the Finnish game version. The data were calculated from the first exposure of each player to each speech–sound pair.

Multidimensional scaling (MDS) and Fechnerian scaling were applied to the probability data. Since the data is asymmetrical, metric MDS cannot be applied directly. Thus, the data had to be transformed into a proper metric using Fechnerian scaling and then, coordinates of the letters were calculated using metric MDS. We examined the results visually and compared the obtained spatial layout of the letters to that of the International Phonetic Alphabet (IPA). It was found that the layout obtained from the probability data roughly corresponds to that of the IPA, which is based on phonetic expert knowledge.

Keywords: Fechnerian scaling, multidimensional scaling (MDS)

Experimental Analysis of Incomplete Preferences

Stéphane Deparis
LGI
Ecole Centrale Paris
e-mail: stephane.deparis@ecp.fr

Vincent Mousseau
LGI
Ecole Centrale Paris
e-mail: vincent.mousseau@ecp.fr

Meltem Oztürk
LAMSADE
Université Paris Dauphine
e-mail: ozturk@lamsade.dauphine.fr

Some multicriteria decision models allow decision-makers to express that two alternatives are incomparable: i.e. no strict preference nor indifference holds. Various motives can lead decision-makers to express incomparability: uncertainty on evaluations of the alternatives, unsufficient experience in the decision field, refusal to endorse a commiting decision... This research investigates incompleteness of preferences resulting from multicriteria conflict. In a conflictual comparison, each alternative is superior to the other on at least one attribute (i.e. no dominance holds).

In this work, we investigate empirically the effect of conflict between alternatives and proximity of the isopreference curves to which they belong on the tendency to express incomparability. We test the hypothesis that comparisons involving alternatives located on the same isopreference curve, and with a high conflict are more likely to elicit incomparability statements. We also test the *confused symmetry hypothesis* following which when assessed by elicitation technique allowing indifference as the only symmetrical answer, decision-makers will use it to express indifference or incomparability, indiscriminately.

We carried out a behavioral experiment on 47 undergraduate students at Ecole Centrale Paris, who were likely to be looking for an accomodation for their upcoming training course. Their main task was to make pairwise comparisons on apartments which differed on rent and accessibility. We found that a greater conflict does lead to a greater number of incomparability statements, but also that proximity of isopreference curves does not increase incomparability. Our data strongly confirms the *confused symmetry hypothesis*, and we propose a heuristics model following which decision-makers first choose to express a strict or symmetrical preference, then determine which symmetrical preference fits their "views" or their thoughts better (if indifference and incomparability are both allowed). Moreover, we found that for comparisons involving alternatives located on the same isopreference curve, incomparability decreases with their overall value.

Keywords: multicriteria decision, preference elicitation, conflict, incomparability

The Signal Processing Approach to Human Classification, Part I: Empirical Data

Justin A. MacDonald
Department of Psychology
New Mexico State University
e-mail:jmacd@nmsu.edu

J D Balakrishnan
Statistics Department
California Polytechnic State University
e-mail: xxjdbxx@hotmail.com

Over the past ten years, we have argued that classical signal detection theory's representation of the decision making strategy as the placement of a decision criterion or boundary in an information or perceptual space is fundamentally wrong, despite the widespread belief that detection theory successfully distinguishes perceptual from decisional factors in two-choice classification tasks. In this talk we present the results of an empirical study demonstrating, in concrete terms, the problem with the classical detection model. In a numerosity discrimination task, the total number of asterisks to be displayed briefly on the screen was drawn from one of two distributions differing only in their means. Subjects were asked to guess, on the basis of this statistical/perceptual information, the distribution (category) from which the stimulus was drawn. An eye tracker was employed to collect data about the stimulus sampling behavior of the subjects on each trial, making it possible to relate decision times to local densities of asterisks in the foveal region. As expected, d prime was virtually constant when comparing groups by response preferences, suggesting that decision biases can be related to shifts in a decision boundary. However, a negative relationship was found between d prime and the number of eye fixations made prior to a response. More importantly, we found clear evidence of a strategic (dynamic) stopping rule: subjects were more likely to stop sampling the stimulus after fixating on highly diagnostic information in the display (very high or very low local density). The assumptions of detection theory can be relaxed in many ways without losing the intuitively attractive concept of a decision criterion. However, strategic stopping rejects this notion in absolute terms, supporting instead the second class of dynamic signal processing models developed by the early detection theorists, the so-called sequential sampling models.

Keywords: signal detection theory, decision criterion, response bias, decision processes, sequential sampling models, sensitivity, speed-accuracy trade-offs

The Signal Processing Approach to Human Classification, Part II: Dynamic Processes

J D Balakrishnan
Statistics Department
California Polytechnic State University
e-mail: xxjdbxx@hotmail.com

Justin A. MacDonald
Engineering Psychology Program
New Mexico State University
e-mail:jmacd@nmsu.edu

Having documented (in Part I) several fundamental empirical mispredictions of the decision criterion construct in classical signal detection theory, we argue that despite its apparent success, detection theory never lived up to the promise of its authors or developed as they originally intended. When the decision process is dynamic, it is not possible to control for the effects of response preferences while ignoring differences in response times. In Part II, we present a robust statistical decision making solution to the problem of measuring dynamic discriminative skill, making it possible to take both accuracy and decision times into account when analyzing discrimination data. The technique produces a measure that is invariant under both response preference and time pressure manipulations and, as a byproduct, a qualitative description of the bivariate distribution of sensory and non-sensory (response execution) components of the observable response time.

Keywords: signal detection theory, decision criterion, response bias, decision processes, sequential sampling models, sensitivity, speed-accuracy trade-offs

Causal Explanations for Noisy Data: Function Estimation

Dan Little
Indiana University, University of Melbourne

Richard Shiffrin
Indiana University
e-mail: shiffrin@indiana.edu

We study inferences about the functional forms that underlie noisy data. The data are shown as the relation of two variables. The inferences are likely to depend on the (implicit) causal model by which the observer chooses to balance good fit and simplicity of explanation. In addition the inferences are likely to depend on the (implicit) causal model the observer has for the source of noise in the observations. The data consist of estimated functions for many different sets of noisy data, noisy sets that vary in form, the presence of gaps and extrapolation regions, and anomalous points that appear to deviate from the pattern of other data points. In one study, we explore human models of error by comparing responses to datasets that have anomalous observations and datasets with identical datasets that have the anomalous observations removed. Different groups of observers were given instructions which either a) made no mention of the odd observations, b) implied that odd observations were meaningless (i.e., glitches) and should be ignored or c) emphasized that odd observations were meaningful and could provide information about the underlying functional form. Modeling of the data sets and the observers responses were carried out with Gaussian process regression, with kernels representing simple polynomials of low degree and also a similarity based function class loosely analogous to spline fitting. In such modeling, noise is typically assumed to be normally distributed but we used a hierarchical Dirichlet process mixture of Gaussian processes in which some of the data could be assigned to a contaminant process. Observers told that there were never any glitches were more likely to bend their explanatory function to include the odd point than observers who were told nothing about the glitches. Paradoxically, observers told odd data points might be glitches also bent their functions more to include them. These observations were verified by the modeling, modeling that provided insight into the differences among observers in their willingness to balance good fit and simplicity, and their willingness to attribute anomalous data to contaminant processes.

Selective Probabilistic Causality

Ehtibar N. Dzhafarov
Purdue University
e-mail: ehtibar@purdue.edu

Janne V. Kujala
University of Jyväskylä
e-mail: jvk@iki.fi

A general definition and a criterion (a necessary and sufficient condition) are formulated for an arbitrary set of external factors to selectively influence a corresponding set of random variables, jointly distributed at every treatment (i.e., a set of factor values containing precisely one value of each factor). The variables are selectively influenced by the corresponding factors if and only if there is a jointly distributed set of random variables, one variable for every value of every factor, such that every subset of this set that corresponds to a treatment is distributed as the original variables at this treatment. We call this the *joint distribution criterion* for selective influence. It is applicable to any set of random entities (not necessarily numeric) and any set of factors. The *distance tests* (necessary conditions) for selective influence previously formulated for two random variables in a two-by-two factorial design are extended to arbitrary sets of factors and random variables. A distance test consists in choosing a number $p \geq 1$, two distinct factors, μ and ν, and two distinct values (x^μ, u^μ) and (y^ν, v^ν) for each of them, and ascertaining whether $\max\{Dx^\mu y^\nu, Dx^\mu v^\nu, Du^\mu y^\nu, Du^\mu v^\nu\} \leq \frac{1}{2}\left(Dx^\mu y^\nu + Dx^\mu v^\nu + Du^\mu y^\nu + Du^\mu v^\nu\right)$, where D for two factor values is defined as $(E(|A-B|^p))^{1/p}$, with A and B being the random variables (or some measurable transformations thereof) corresponding to these factor values. If the inequality is violated for at least one choice of (x^μ, u^μ), (y^ν, v^ν), p, and of the measurable transformations, selective influence is ruled out.

Applying a Model of Learning to Sleep Deprivation Data

Janne V. Kujala
Agora Center
University of Jyväskylä
e-mail: jvk@iki.fi

Airi Kilpeläinen
Department of Psychology
University of Jyväskylä
e-mail: airi.kilpelainen@jyu.fi

In general, sleep loss is considered to impair cognitive functions. In our study we examined how the total 60-hour sleep deprivation (SD) affects learning new information (SD group; $n = 20$). Auditory-visual associative learning was examined in five measurent points where the vigilance is at its lowest (at 4 pm and 4 am) according to human circadian rhythm. At each measurement point, the same set of eight new hiragana symbols with corresponding syllable sounds was presented in two identical associative learning sessions one hour apart. Each learning session continued until each association was correctly recognized three times in successive presentations. Previous statistical analyses (repeated measures ANOVA) of the data have shown that the overall performance in this task does not deteriorate under SD. However, in the second night of SD there was no difference between the two identical learning sessions: the first learning session did not reduce the number of trials needed to learn the same items again.

In this paper, we studied the data in more detail applying a mathematical model of learning by Atkinson and Crothers (1964), which assumes that each item (association) to be learned can be in three different states, which we label "not learned", "temporarily learned", and "learned". A "not learned" item can become "temporarily learned" when presented and a "temporarily learned" item can return to the "not learned" state if other items are presented in between, or move to the "learned" state if presented again. A transition matrix models the probabilities of each of these possible transitions. As the subject can guess when not certain, or make careless mistakes, there is randomness in the answers. Therefore, Bayesian estimation techniques were used. We estimated the parameters of the model for each participant as a function of the SD time.

Interestingly, the results show that the learning rate parameter increased over the SD period. One explanation for this may be that the participants found the task more and more stimulating as the SD time increased. Moreover, the forgetting rate of "temporarily learned" items shows a circadian rhythm together with a small decreasing trend. However, it should be noted that these are initial results, the model has not been extensively tested.

Keywords: Auditory-visual association, learning, sleep deprivation, hidden markov model, dynamic estimation.

Modeling the Coevolution of Event Memory and Knowledge

Richard Shiffrin
Indiana University
e-mail: shiffrin@indiana.edu

Angela B. Nelson
Indiana University

Gregory Cox
Indiana University

Knowledge grows from the events we experience, and events are coded in terms of the current state of knowledge. Memory holds both knowledge and events, and both contribute to memory storage, growth of knowledge, and retrieval from memory of events and knowledge. We present studies designed to provide data critical for modeling these processes, and a model termed Storage and Retrieval of Knowledge and Events (SARKAE). The studies involve extensive training of novel (to the participants) Chinese characters. Training in different studies uses visual search or character matching, and we vary the amount of training per character, and the associative structure of pairs of characters. Knowledge develops in training when a character is repeatedly presented because because each presentation produces an incomplete and error prone event trace, and also adds some of the same event information to that characters knowledge trace. Following training, transfer tests are given: episodic recognition, pseudolexical decision, and perceptual identification. SARKAE uses the same basic mechanisms to explain the results of both training and transfer, and thus represents a first step toward a model of the coevolution of event memory and knowledge.

Nonstandard applications of structural equation modeling

Peter Molenaar
The Pennsylvania State University

The general structural equation model (SEM) for the analysis of inter-individual variation has the same form as the state-space model (SSM) for the analysis of intra-individual variation. Some consequences of this formal relationship will be discussed including a) Using the transformation of SSMs to transfer function models to define new model equivalences for SEM (with the surprising result that all SEMs are nested); b) Applying optimal control theory for linear Gaussian SSM in the context of SEM; c) Applying SEM to fit bilinear dynamic models to fMRI time series; d) Inferring possible applications of SSM from the accommodation of RTs obtained in additive factorial designs to SEM.

Bayesian Adaptive Estimation of Psychometric Threshold and Slope: A Comparison of Methods

Miguel A. Garcia-Perez
Departamento de Metodologia
Facultad de Psicologia
Universidad complutense
e-mail: miguel@psi.ucm.es

Rocio Alcala-Quintana
Departamento de Metodologia
Facultad de Psicologia
Universidad complutense
e-mail: ralcala@psi.ucm.es

Psychophysical research usually involves the estimation of sensory thresholds, which in practice represent some percentage point on the psychometric function describing performance on the task. The accuracy of Bayesian adaptive methods of threshold estimation is known to depend on the adequacy of their parametric assumptions, particularly that about the support (inverse of slope) of the psychometric function. For this reason, methods that concurrently estimate threshold and slope have been proposed in the past few years, and their performance has been separately assessed in independent simulation studies. Because criteria and conditions varied across those studies, their results cannot be used in a comparison of their relative efficiency. We thus carried out a simulation study to evaluate three Bayesian adaptive methods for the concurrent estimation of threshold and slope, namely, (1) a simple method that uses two independent Bayesian runs to track two different percent points so that slope is finally estimated from the distance between the two resultant estimates, (2) a method that also uses two separate and independet runs to gather data, but which obtains Bayesian estimates of threshold and slope from the posterior distribution, and (3) an entropy-based method that governs both the deployment of trials and the final estimation. These methods were tested in conditions in which the observers lapse or do not lapse (i.e., make "finger errors" upon responding), and for the case of two-alternative forced-choice (2AFC) detection and discrimination tasks. In 2AFC detection tasks, the entropy-based method was superior when observers do not lapse, but posterior Bayesian estimators were superior in the presence of lapses. As for 2AFC discrimination tasks, the simple method was superior in the absence of lapses, but Bayesian estimators were again superior in the presence of lapses.

Keywords: Adaptive Bayesian estimation, psychometric function, threshold, slope

Estimating Psychometric Functions in Nonstationary Observers

Ingo Fründ
Modelling of Cognitive Processes
Berlin Institute of Technology and Bernstein Center for Computational Neuroscience
e-mail: ingo.fruend@tu-berlin.de

Valentin Haenel
Modelling of Cognitive Processes
Berlin Institute of Technology and Bernstein Center for Computational Neuroscience
e-mail: valentin.haenel@mail.tu-berlin.de

Felix A. Wichmann
Modelling of Cognitive Processes
Berlin Institute of Technology and Bernstein Center for Computational Neuroscience
Berlin, Germany
e-mail: felix.wichmann@tu-berlin.de

The psychometric function relates a physical dimension, such as stimulus contrast, to the responses of an observer. This relation is conveniently summarized by fitting a parametric model to the responses. In fitting such a model, we typically assume the responses to be independent of each others and that responses at the same stimulus level follow the same distribution. However, there is evidence that casts doubt on the validity of this independence assumption: responses in psychophysical tasks are mutually dependent due to factors such as learning, fatigue, or fluctuating motivation. These kinds of dependencies are summarized as nonstationary behavior. From a theoretical point of view, nonstationarity renders inference about psychometric functions incorrect – it can result in rejection of otherwise correct psychometric functions or wrong credible intervals for thresholds and other characteristics of the psychometric function. However, it is not known how severe these errors are and how to properly correct for them.

We simulated a number of observers with different types of nonstationary behavior. Psychometric functions were fitted for a large number of experimental settings, defined by the number of trials, the number of experimental blocks, and the task (2AFC vs yes-no). In general, nonstationary behavior resulted in severly underestimated credible intervals. We present criteria to identify psychometric functions that are influenced by nonstationarity, and develop strategies that can be applied in different statistical paradigms — frequentist and Bayesian — to correct for errors introduced by nonstationary behavior.

A software that automates the proposed procedures is available.

Keywords: psychometric function, nonstationary observers, bayesian analysis

Bayesian Adaptive Optimal Design for Discriminating Models of Cognition

Jay Myung
Ohio State University
e-mail: myung.1@osu.edu

Daniel Cavagnaro
Ohio State University
e-mail: cavagnaro.2@osu.edu

Mark Pitt
Ohio State University
e-mail: pitt.2@osu.edu

Experimentation is fundamental to the advancement of science, whether one is interested in studying the neuronal basis of a sensory process in cognitive neuroscience or assessing the efficacy of a new drug in clinical trials. Adaptive design optimization, in which the information learned from each experiment is used to inform subsequent experiments, is a particularly attractive methodology because it can potentially reduce the time required for data collection while simultaneously increasing the informativeness of the knowledge learned in the experiment. More concretely, the problem to be solved in adaptive sequential design optimization for model discrimination is to identify an experimental design under which one can infer the underlying model, among a set of candidate models of interest, in the fewest possible steps. This problem is challenging because of the many, sometimes arbitrary, choices that must be made when designing an experiment. Nevertheless, it is generally possible to find a design that is optimal in a defined sense. In this paper, addressing the design optimization problem in discrimination of formal models of cognition, we apply a simulated-based Bayesian method that was recently introduced in statistics (Muller, Sanso & De Iorio, 2004). We use a utility function based on mutual information, and give three intuitive interpretations of the utility function in terms of Bayesian posterior estimates. Finally, we demonstrate the potential of adaptive design optimization for improving experimentation in psychology in discrimination of formal models of forgetting and numerical estimation with simulated as well as human participants.

A Formal Model of the Spread and Demise of Concepts in Social Groups

Enrique Canessa
Facultad de ingeniera y ciencias
Universidad Adolfo Ibez
e-mail: ecanessa@uai.cl

Sergio Chaigneau
Facultad de psicologa
Universidad Adolfo Ibez
e-mail: sergio.chaigneau@uai.cl

Ariel Quezada
Facultad de psicologa
Universidad Adolfo Ibez
e-mail: ariel.quezada@uai.cl

Generally, cognitive science treats concepts as an individual-level phenomenon that allows people to predict the outcomes of their transactions with the world. In work we report here, we develop a mathematical framework that treats conceptualization as a group-level phenomenon that spreads in a group through individual-level interactions. This framework makes some very simple assumptions: (1) There are many different versions of one similar conceptualization (i.e., even if people conceptualize a situation similarly, they dont share all their conceptual content); (2) Therefore, when we infer that our view agrees with someone elses view, we are subject to true agreement (i.e., we will continue to be in agreement if we explore the issue further), but also to false agreement (i.e., we will fail to be in agreement if we explore the issue further); (3) Regardless whether agreement is true or false, it increases the probability that we will seek further interactions with that same person or source of information; (4) A conceptualization that is useful for agreement (true or false), strengthens its salience in individual minds, whereas a conceptualization that isnt useful for agreement, weakens it salience in individual minds. These assumptions can be formally represented by a static conditional probabilistic model, whose results are then used in an ergodic Markov chain with 4 states (increased salience at moment t, decreased salience at moment t, increased salience at moment $t+1$, decreased salience at moment $t+1$), to assess the dynamical characteristics of the model. Assuming there are no structural restrictions on interactions, our Markov chain allows formal definitions of conditions under which all versions of the same conceptualization will end up strengthening their salience in a group, conditions under which some versions will strengthen while others will weaken their salience, and conditions under which all versions will end up weakening their salience. Additionally, taking partial derivatives of the equations that define the transition probability matrix of the Markov chain, we are able to analyze the systems sensitivity to various parameters, such as initial salience of a conceptualization and the probabilities of true and false agreement. The findings of the mathematical model agree with the results of an agent-based simulation of our idealized system, which lends more support to our conclusions. We believe this mathematical framework may allow explaining the spread or demise of conceptualizations in social groups, and the emergence of polarized social views, all important issues to sociology and psychology.

Keywords: Markov chain, conceptualization process, social influence

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UNIVERSITY OF JYVÄSKYLÄ

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