



39<sup>th</sup> European Mathematical Psychology Group Meeting  
Graz, Austria, September 7 – 11, 2008

## Program and Abstracts



**Program Committee:**

Dietrich Albert, Thomas Augustin,  
Cord Hockemeyer, & Christof Körner

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EMPG2008 Meeting

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# **General Information**

## **Get-Together Meeting**

The informal Get-Together meeting takes place on Sunday, September 7, 19:00 at the restaurant Glöckl Bräu in Graz, Glockenspielplatz 2-3, Tel.: +43 316 81 47 81.

## **Registration**

The registration desk is open during lecture hours starting at 08:30 (on Monday at 08:00) in the morning. It is located in the Foyer in front of the lecture rooms (HS 06.02, HS 06.03). The phone number of the registration desk is +43 676 68 09 409. Registration fees for the EMPG Meeting are EUR 150 for regular participants and EUR 50 for students (please bring your student ID) + EUR 25 for late registration after August 7. Conference Fees include the conference booklet of abstracts, coffee breaks, lunch vouchers, and the conference dinner (for the participants). If you have not yet transferred the money please pay the fee in cash at the registration desk.

## **Opening Session**

The opening session will take place on Monday, September 8, 2008, from 09:00 to 09:30 at HS 06.02, Universitätsplatz 6 (“Vorklinik”), 8010 Graz.

## **Sessions and Lecture Rooms**

The sessions start on Monday, September 8, 2008, 10:00, according to the time schedule. The sessions take place at the University of Graz, Universitätsplatz 6 (“Vorklinik”). Lecture rooms are the rooms HS 06.02 and HS 06.03. PC & beamer and overhead projector are available.

## **Uploading Presentations**

Please upload your presentation at the registration desk or in the lecture room at the latest before your session.

## **Closing Session**

The closing session will be on Thursday, September 11, 2000, 11:45 in HS 06.02.

## Sight-Seeing

The Graz area offers many interesting sight-seeing points. The conference folder contains a map of Graz and information about the highlights of the town.

## City Tour

The guided city tour starts on Tuesday, September 9, 2008, at 17:30 at the Hauptplatz at the main entrance of the city hall. The tour will end at the Restaurant Landhauskeller.

## Conference Dinner

The Conference Dinner takes place on Tuesday, September 9, 19:00 at the restaurant Landhaus-Keller, Schmiedgasse 9, Tel.: +43 316 83 02 76.

## Internet Access

W-LAN will be available in the Foyer and the Lecture Rooms. There are also PCs available in the Foyer to look up your E-mail (please use the login name '08t002ho' and the password 'empg2008').

## Public Telephone

There are two public telephones located near the entrance of the building *Universitätsplatz 6* (coins, phone-card, or credit card required).

## Public Transport

You find a map of the public transport system of Graz in the conference folder. Tickets are available from the driver (also 24 hour tickets) or in a Trafik (strip tickets or weekly ticket).

## Special Hint

You can buy phone-cards, bus tickets, newspapers, and tobacco in the Trafik. There are some near the conference venue at Zinzendorfgasse and at Heinrichstrasse (near Goethestrasse), and everywhere throughout the town.

## **Acknowledgement**

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- Bundesministerium für Wissenschaft und Forschung
- Steiermärkische Landesregierung
- Bürgermeister der Stadt Graz
- Rektor der Karl-Franzens-Universität
- Dekan der Naturwissenschaftlichen Fakultät
- Institut für Psychologie
- Ulbel & Freidorfer

## **Program Committee**

Dietrich Albert (chair), Thomas Augustin, Cord Hockemeyer, Christof Körner

## **Organising Committee**

Helga Aigner, Dietrich Albert (chair), Thomas Augustin, Christina Eder, Cord Hockemeyer, Katharina Kaschnitz, Michael D. Kickmeier–Rust, Christof Körner, Ilona Lipp, Antonia Maas, Alexander Nussbaumer, Christian Poglitsch, Annemarie Seither–Preisler, Gudrun Wesiak



## Time Schedule

	<b>Measurement</b>	HS 06.03
	<i>Chair: Jean-Paul Doignon</i>	
	<i>Jean-Paul Doignon</i>	
	Semiorder Representations and Total Dual Integrality	
	<i>Jean-Pierre Desclés, Anca Pascu</i>	
	Logic of Deterimation of Objects and Treillis de Galois	
12:00 – 13:00	<b>Invited Lecture</b>	HS 06.02
	<i>Adele Diederich</i>	
	The Time-Window-of-Integration (TWIN) Model: A Framework for Crossmodal Interaction	
13:00 – 14:00	<b>Lunch Break</b>	
14:00 – 16:00	<b>2 Parallel Sessions</b>	
	<b>Psychological Testing I</b>	HS 06.02
	<i>Chair: Marco J. Maier</i>	
	<i>Marco J. Maier, Rainer W. A. Alexandrowicz</i>	
	Using IRT-Models to detect and quantify linebreak position-effects in psychological tests: linebreak Pitfalls and possibilities	
	<i>Ingrid Koller, Judith Glück</i>	
	Measuring change using item response models: A comparison of different approaches	
	<i>Sara Giovagnoli, Mariagrazia Benassi, Antonio Cataldo, Roberto Bolzani</i>	
	The Rasch Model: Comparison between Rumm, WinSteps and Logistic Regression Approaches	
	<i>Carlo Chiorri</i>	
	An alternative statistical procedure for testing within-construct issues of the Emotional Intelligence Scale (EIS)	

Time Schedule

**Formal Models of Neural and Cognitive Processes I** HS 06.03

*Chair: Donald Laming*

*Donald Laming*

Free Recall: A resuscitation of the Total Time Hypothesis

*Andreas Voss, Karl Christoph Klauer*

Mapping Response Tendencies with Ratcliff's (1978) Diffusion Model

*Bart Ons, Johan Wagemans*

Mutual information in categorization models

*Tarik Hadzibeganovic, Dietrich Stauffer, Christian Schulze*

A three-state three-trait Axelrod model for language choice dynamics

16:00 – 16:30 **Coffee Break** Foyer

16:30 – 17:30 **2 Parallel Sessions**

**Psychological Testing II** HS 06.02

*Chair: Miguel A. García-Pérez*

*Rocío Alcalá-Quintana, Miguel A. García-Pérez*

The relation between standard error of estimation and residuals in computerized adaptive testing

*Miguel A. García-Pérez, Rocío Alcalá-Quintana, Eduardo García-Cueto*

Comparative performance of several setup options in a concurrent common-item equating design involving Likert-type items

**Formal Models of Neural and Cognitive Processes II** HS 06.03

*Chair: Uwe Mortensen*

*Uwe Mortensen*

Detection by neuron populations.

*Chingis A. Izmailov, Mikhail M. Zimachev*

Dual - Channel Model of Frog's Achromatic Vision

17:30 – 18:30 **Invited Lecture** HS 06.02

*Jim Townsend*

Forty Years of Serial and Parallel Processing

## Tuesday, September 9, 2008

- 09:00 – 10:00    **Invited Lecture**    HS 06.02  
*Jeffrey N. Rouder*  
Item-response models for measuring human thresholds
- 10:00 – 11:00    **2 Parallel Sessions**
- Perception, Psychophysics and Reaction Times I**    HS 06.02  
                    *Chair: Richard D. Morey*  
  
                    *Richard D. Morey, Jeffrey N. Rouder, Paul L. Speckman*  
                    A truncated-probit item response model for estimating psychophysical thresholds  
  
                    *S. Alex Marinov*  
                    Discovering Structures in Mixed (Numerical & Categorical) Data Using Dimensional Analysis
- Decision Processes and Game Theory I**    HS 06.03  
                    *Chair: Michel Regenwetter*  
  
                    *Michel Regenwetter, Clinton P. Davis-Stober*  
                    Luce's Axiom Testing Challenge and Possible Solutions  
  
                    *Janne V. Kujala, Ulla Richardson, Heikki Lyytinen*  
                    Adaptive estimation of the parameters of Luce's choice model
- 11:00 – 11:30    **Coffee Break**    Foyer
- 11:30 – 13:00    **2 Parallel Sessions**
- Perception, Psychophysics and Reaction Times II**    HS 06.02  
                    *Chair: Martin Lages*  
  
                    *Martin Lages, Suzanne Heron*  
                    Modeling the perception of binocular 3-D motion direction  
  
                    *Luigi Beghi, Elisabetta Xausa, Mario Zanforlin*  
                    A mathematical model of the stereokinetic cone  
  
                    *Vittore Perrucci, Gianmarco Altoè*  
                    Interindividual Differences in Mental Rotation of School-Aged Children: A Multilevel Growth Model Approach

Time Schedule

- Decision Processes and Game Theory II** HS 06.03  
*Chair: August Fenk*  
*August Fenk*  
Decomposing “lawlikeness”  
*Michele Bernasconi, Christine Choirat, Raffaello Seri*  
Psychological Distortions in Decision Making  
*Michele Lombardi*  
Minimal covering set solutions
- 13:00 – 14:00 **Lunch Break**
- 14:00 – 15:30 **2 Parallel Sessions**
- Perception, Psychophysics and Reaction Times III** HS 06.02  
*Chair: Hans Colonius*  
*Mathias Benedek, Christian Kaernbach*  
Decomposition of skin conductance data by means of deconvolution  
*Hans Colonius, Adele Diederich, Rike Steenken*  
Visual-Auditory Integration in Saccadic Reaction Time: Recent Results
- Decision Processes and Game Theory III** HS 06.03  
*Chair: Michel Regenwetter*  
*Chung-Ping Cheng, Ching-Fan Sheu*  
Learning Models and the Iowa Gambling Task  
*Galina M. Golovina*  
A Model of the “Game in Location”
- 15:30 – 16:30 **Invited Lecture** HS 06.02  
*Iris van Rooij*  
Dealing with intractability in cognitive modeling: The good, the bad, and the ugly
- 17:30 – 19:00 **Guided City Tour**  
Meeting Point: Hauptplatz at the main entrance of the city hall
- 19:00 – 22:30 **Conference Dinner**, Landhauskeller, Schmiedgasse 9

## Wednesday, September 10, 2008

- 09:00 – 10:00    **Invited Lecture**    HS 06.02  
*Ehtibar Dzhafarov*  
Perceptual Discrimination: Old Problems and New Perspectives
- 10:00 – 11:00    **2 Parallel Sessions**
- Perception, Psychophysics and Reaction Times IV**    HS 06.02  
                         *Chair: Thomas Augustin*  
  
                         *Thomas Augustin*  
                         The problem of meaningfulness: Stevens' power law, Weber's law, and  
                         the near-miss-to-Weber's law  
  
                         *Ragnar Steingrímsson*  
                         Exploration of similarities and differences in loudness and brightness  
                         as informed by mathematical modelling
- Applied Mathematical Psychology I**    HS 06.03  
                         *Chair: Cara Kahl*  
  
                         *Cara Kahl, Hans Hansen*  
                         Modeling an Environment to Facilitate Creativity  
  
                         *Tatyana N. Savchenko, B.B. Velichkovsky*  
                         Development of model of an estimation of individual stability to stress
- 11:00 – 11:30    **Coffee Break**    Foyer
- 11:30 – 13:00    **2 Parallel Sessions**
- Knowledge Space Theory & FCA**    HS 06.02  
                         *Chair: Vincenzo Barbaro*  
  
                         *Pasquale Anselmi, Vincenzo Barbaro, Egidio Robusto, Luca Stefanutti*  
                         A Probabilistic Skill Map Model for Multilevel Learning Processes  
                         with Several Learning Objects  
  
                         *Vincenzo Barbaro, Luca Stefanutti, Egidio Robusto*  
                         Validation of a Probabilistic Knowledge Structure based on Higher-  
                         order Cognitive Skills

## Time Schedule

- Applied Mathematical Psychology II** HS 06.03  
*Chair: Christof Körner*  
*Mauro Francaviglia, Marcella G. Lorenzi, Simona Paese*  
*A. Sorrentino*  
The use of Meditation in learning-teaching processes of Mathematics  
*Mauro Francaviglia, Rocco Servidio, Marcella G. Lorenzi*  
Children learn with gestures
- 13:00 – 14:00 **Lunch Break**
- 14:00 – 15:00 **2 Parallel Sessions**
- Non Numerical Item Analysis** HS 06.02  
*Chair: Andrea Spoto*  
*Andrea Spoto, Eraldo Nicotra, Giulio Vidotto*  
A Formal Concept Analysis Approach to Statistical Hypothesis Testing  
*Anatol Sargin, Ali Ünlü*  
Improved inductive item tree analysis
- Applied Mathematical Psychology III** HS 06.03  
*Chair: Maxim A. Kharchenko*  
*Maxim A. Kharchenko*  
Interval scales modelling in drawn projective techniques  
*Mehrdad Mazaheri, Abdulwahab Pourghaz*  
A Comparison of Unipolar and Bipolar Rating Scales for Measuring SWB
- 15:00 – 16:00 **Invited Lecture** HS 06.02  
*Jean-Claude Falmagne*  
On meaningful scientific laws on bounded domains: A theoretical analysis
- 16:00 – 16:30 **Coffee Break** Foyer
- 16:30 – 18:00 **Symposium “Knowledge and Competence Structures and their Applications”** HS 06.02  
*Jürgen Heller*  
Empirical Validation of Knowledge Structures: A Resampling Perspective  
*Ali Ünlü, Anatol Sargin*  
Evaluating fit measures for quasi orders

## Thursday, September 11, 2008

- 09:00 – 10:30    **Symposium “Knowledge and Competence Structures and their Applications”**    HS 06.02  
*Reinhard Suck*  
Applying matroids to media, knowledge spaces, and other structures  
*Luca Stefanutti*  
Probabilistic Models for Skill Maps
- 10:30 – 11:00    **Coffee Break**    Foyer
- 11:00 – 11:45    **Symposium “Knowledge and Competence Structures and their Applications”**    HS 06.02  
*Cord Hockemeyer*  
Real-Time Skill Assessment
- 11:45 – 12:00    **Closing Session**    HS 06.02

## Abstracts

### The relation between standard error of estimation and residuals in computerized adaptive testing

Rocío Alcalá-Quintana  
Miguel A. García-Pérez

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The so-called standard error of estimation (SE) “computed as the inverse square root of the test information at the estimated ability” has become a popular index of precision in computerized adaptive testing (CAT). Use of SE overlooks the fact that the inverse of the test information has only proven to be the lower bound of the true standard error under certain asymptotic conditions, whereas CATs typically result in the administration of a small number of items (as few as possible, indeed). Nevertheless, SE has come to play an important role in the definition of stopping rules according to which the administration of items is discontinued when the SE falls below some reasonable but arbitrary value, implicitly assuming that there is a monotone increasing relationship between SE and the absolute magnitude of residuals in small sample conditions. In this study, we have used simulation methods to derive the relation between SE and residuals in adaptive administration of tests under both the 3PL model (for multiple-choice items in achievement tests) and the graded response model (for 5-point Likert-type items in inventories). We have used item parameters drawn out from banks of actual adaptive tests as well as simulated item pools. Our simulations implemented (1) fixed-length CATs with different numbers of items ranging from 10 to 100, (2) the maximum information criterion to select each item and (3) the expected a posteriori (EAP) ability estimator. Our results reveal that SE bears no relation to residuals, and that the precision of a given CAT estimate is only determined by the number of items that were administered to obtain it. Further analyses show that the same lack of relation is found between residuals and either the Bayesian probability interval or the Bayesian posterior standard deviation.

**Keywords:** Computerized adaptive testing, standard error of estimation, 3PL model, graded response model, Likert-type items

## A Probabilistic Skill Map Model for Multilevel Learning Processes with Several Learning Objects

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In our work the knowledge state of a student is defined as the set of all skills possessed by him (Doignon, 1994; Albert & Lukas, 1999). Moreover, the learning process of a student is modelled as a function of the interaction between the knowledge state of that student and the effect of several learning objects in different time steps. A probabilistic skill map model has been developed for multilevel learning processes with more than one learning object. The probabilistic model incorporates parameters for measuring the effect of the learning objects on the skills. This model has been applied to evaluate the effect of 6 learning objects on the responses of two groups of University students to 15 problems. A three-steps learning process was considered. In this perspective, effective learning objects should increase the probability of learning the skills required to solve the problems, while ineffective learning objects shouldn't. We used 3 effective and 3 ineffective learning objects; the effective ones were presented to a first group and the ineffective ones to a second group. The results of the application are presented and discussed.

### **References:**

- Albert, D. & Lukas, J. (1999). *Knowledge Spaces: Theories, Empirical Research, Applications*. Lawrence Erlbaum Associates: Mahwah, NJ.
- Doignon, J.-P. (1994). Knowledge spaces and skill assignments. In Fischer, G. & Laming, D. (Eds). *Contributions to Mathematical Psychology, Psychometrics, and Methodology*. Springer: Berlin.

**Keywords:** Skill maps, learning objects, learning processes, knowledge structures

# The problem of meaningfulness: Stevens' power law, Weber's law, and the near-miss-to-Weber's law

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Stevens and others collected a vast set of data on a wide variety of sensory modalities that produced power functions of the form

$$\varphi_s(t) = \alpha_s t^{\beta_s}, \quad t > 0. \quad (1)$$

Equation (1) indicates that a physical stimulus of the intensity  $t$  appears to be  $\alpha_s t^{\beta_s}$ -times more intense than a standard stimulus of the intensity  $s$ . Although Equation (1) is widely used in psychophysics, only few researchers pointed to potential problems resulting from the fact that the parameters  $\alpha_s$  and  $\beta_s$  depend on the referent intensity  $s$  and, consequently, on the standard stimulus  $x$  and the physical stimulus scale  $f$ .

For this reason, I present a reformulation of Stevens' power law which clarifies the influence of the physical stimulus scale  $f$  and the standard stimulus  $x$  on the parameters in Stevens' power law. A mathematical argument is presented that the exponent in Stevens' power law is invariant under changes of the stimulus scale  $f$  (i.e., can be interpreted in a meaningful way), only if the physical quantities are measured on a ratio scale.

To address the question whether the exponent is also invariant under changes of the standard stimulus  $x$ , an empirically testable axiom (termed weak multiplicativity) is introduced. To test for weak multiplicativity, one might ask a subject to produce a stimulus that appears to be 2-times more intense than a standard stimulus  $x$ , and in a subsequent trial to halve the result ( $\times 2 \times \frac{1}{2}$  adjustment). If weak multiplicativity is satisfied, then the  $\times 2 \times \frac{1}{2}$  adjustment should agree with the  $\times 1$  adjustment. It is argued that, under quite plausible side conditions, the axiom of weak multiplicativity is necessary and sufficient for the power law exponent to be independent of the presented standard stimulus.

Weak multiplicativity was evaluated in a ratio production experiment: Ten participants were required to adjust the area of variable circles to prescribed ratio production factors. Since each participant produced at least 2 violations of weak multiplicativity and a total of 28 out of 40 tests showed statistically significant results, the conclusion is justified that weak multiplicativity fails to hold for the area production of circles. This result casts serious doubts on the well-established practice of comparing power law exponents across different sensory modalities.

Additionally, it is argued that a similar problem applies to Weber's law and its modifications. Hence, I present reformulations of common models of discrimination, like for instance, Weber's law, Guilford's power law, and the near-miss-to-Weber's law. All models rest upon the assumption that the model parameters depend on the underlying physical stimulus scale. By discussing the meaningfulness of the model parameters, we

come to the conclusion that the near-miss-to-Weber's law is superior to Guilford's power law.

**Keywords:** Stevens' power law; Weber's law; near-miss-to-Weber's law; meaningfulness; parameters

## Validation of a Probabilistic Knowledge Structure based on Higher-order Cognitive Skills

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Luca Stefanutti  
Egidio Robusto

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The assumption that solving a problem requires both basic and higher-level skills is considered. While basic skills are essentially knowledge about the problem, higher-level skills arise when two or more basic skills have to be combined or used in conjunction in order to produce the correct solution. This assumption was tested on a set of 15 problems on Elementary Probability Theory through an application of the logistic knowledge structure model (Stefanutti, 2006). The solution to each of the 15 problems requires one or more basic skills coming from a set of four. The assignment of the basic skills to the problems in a conjunctive manner, gave rise to a knowledge structure on the set of 15 problems. In an alternative model a set of seven skills was considered: the four basic skills of the previous model plus three additional higher-order skills. In this way a second knowledge structure was obtained. The validation of these two logistic knowledge structures on a data set of 112 University students showed a better fit of the 7-skills model, supporting the hypothesis that higher order skills arise in the solution of the 15 problems.

**Keywords:** Higher-order skills, probabilistic knowledge structures

## A mathematical model of the stereokinetic cone

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The stereokinetic cone is a visual illusion of depth elicited by a circular surface with an off-centre dot, stuck on a platform uniformly rotating with angular speed  $\omega$  in the frontal plane of an observer. After a certain time of monocular inspection, a cone will appear, whose base is the circular contour and whose apex is the off-centre dot. This cone has a well defined height and his axis is tilted in depth, at a well defined angle with respect to the frontal plane. The percept is largely independent of the rotational speed of the stimulus and of its location on the frontal plane. Our mathematical model of this phenomenon is based on a minimal relative motion principle stating that the Visual System transforms the 2D relative velocities of the points of the rotating stimulus (with respect to its perceptual center), attributing to these points an additional velocity component orthogonal to the frontal plane in such a way as to minimize the differences between the lengths of the resulting 3D velocity vectors. A subsequent transient phase (not perceived by the observer) with finite duration  $t = 1/\omega$  has been introduced, which explains for the transition of the rotating stimulus into the percept.

**Keywords:** stereokinetic phenomena, minimum relative motion assumption, stereokinetic cone

## Decomposition of skin conductance data by means of deconvolution

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Electrodermal activity (skin conductance, SC) is one of the most widely used measures of general arousal in psychophysiological research. SC data can be characterized as a superposition of a sequence of phasic skin conductance responses (SCRs) overlying a tonic component. The form of a phasic response can be described by a Bateman function which is assumed to represent the underlying 2-compartment diffusion process of sweat diffusing into and finally out of the dermis. An additional process affecting the observed SCR form may be associated with the opening of pores of sweat ducts (poral valve model, Edelberg, 1993). The observed SC data can be understood to reflect the impulse response of sweat gland activity. In experimental research, SCR amplitudes are often estimated by calculating trough to peak values. However, this method is prone to errors due to non-consideration of the influence of preceding SCRs.

Our approach uses one-dimensional deconvolution in order to unveil the underlying impulse function. An adaptation of the deconvolution procedure allows for an implicit estimation of the additional effect caused by the opening of pores. The obtained impulse function shows distinct deflections and can therefore easily be segmented into discrete impulses. This segmentation allows rebuilding the SC data as superposition of discrete components which can be used for validation of the analysis result. The proposed method seems especially advantageous for data with high SCR rates, as could be shown in an experiment using a short inter-stimulus paradigm.

**Keywords:** decomposition, deconvolution, Bateman function, skin conductance, electrodermal activity, SCR, EDA

## Psychological Distortions in Decision Making

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Several methods commonly used in Decision Making are based on the evaluation by the individual of ratios of relevances of attributes or alternatives. This is what in psychophysics Stevens called "ratio magnitude estimation". Indeed, Stevens' psychophysical theory is sometimes quoted when looking for a rationale for methods of decision through ratio elicitation, in particular as concerns the claim that subjective ratio estimation should be treated as any other form of scientific measurement and acknowledged as exhibiting the usual standard of scientific reliability. However recent advances in the study of the theoretical foundations of ratio estimation, especially by Luce and Narens, has lead to the development of a class of models, called "separable representations", axiomatizing and in several respects generalizing Stevens' power-law model. When using ratios for the evaluation of alternatives in decision models, these psychological distortions should be kept into account. We consider the Analytic Hierarchy Process or AHP as an example. First of all we consider the effect of psychological distortions on the quantities of interest. Then we propose a technique allowing for reducing the effect of these biases and we provide a statistical analysis of the method. At last we analyze the relevance and the feasibility of the proposed method using an experiment of distance evaluation based on a sample of 69 individuals.

**Keywords:** Decision making, Ratio magnitude estimation, Separable representations

## Learning Models and the Iowa Gambling Task

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The expectancy-valence model is proposed to account for the Iowa gambling task, a widely used cognitive task for studying human learning and decision-making processes. In this study, we explore the relationship between the expectancy-valence model and three learning models: Bush-Mosteller's stochastic learning model, the Rescorla-Wagner model, and a logistic regression model for avoidance.

Analogous to the expectancy-valence model, the three models can also be seen as having learning and choice components. During learning, the individual computes the valence based on the payoff of every trial, and then forms the expectancy-valence of each option according to the recent valence and the previous expectancy-valence. The choice component describes how choice probability of each option of the gambling task is related to its expectancy-valence.

We show that the learning component of each of the three models can be formulated as a special case of the learning process represented in the expectancy-valence model. As for the choice component, the logistic regression model is similar to the expectancy-valence model in that each option's choice probability is proportional to the exponent of its expectancy-valence. In contrast, the choice probability of each option is found to be linearly related to its expectancy-valence in both Bush-Mosteller's stochastic learning model and the Rescorla-Wagner model.

Finally, we note that, since the Iowa gambling task has been used in different settings involving different units of gain or loss, parameters of these learning models should be scale free. However, it is observed that not all parameters of the expectancy valence model are scale free. For example, a change of currency unit used in the task resulted in different parameter estimates from fitting the model to data. Comparisons of these parameters across studies using different units of gain and loss should be carefully conducted.

**Keywords:** Expectancy-valence model, learning, decision making, Rescorla-Wagner model

## An alternative statistical procedure for testing within-construct issues of the Emotional Intelligence Scale (EIS)

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Schutte et al (1998)'s Emotional Intelligence Scale (EIS) has been extensively used for research purposes, though a psychometrically sound one-factor structure has never been shown nor results of exploratory factor analyses (EFAs) have been replicated. Three independent Italian adaptation studies, among which this one, could not provide evidence for adequate reliability and validity, suggesting shortcomings in scale development. In their seminal paper, the Authors stated that they adopted Salovey and Mayer (1990)'s ten-dimensional model of Emotional Intelligence that included three broad areas of emotion: Appraisal and Expression, Regulation, and Utilization. They developed a 62-item pool and retained the 33 items that loaded on the first varimax rotated principal component (PC), which were supposed to represent all the facets of Salovey and Mayer's conceptual model. Unfortunately, they never tested the psychometric soundness of such one-factor structure, nor did the subsequent users of the scale (except Petrides and Furnham, 2000, with discouraging results), which were far more interested in its factor structure. Inspecting Salovey and Mayer's graphical representation of the model, EFA does not seem an adequate method for retrieving the hierarchical structure of the facets. A solution may be represented by SAS/STAT VARCLUS procedure. It divides a set of numeric variables into either disjoint or hierarchical clusters. Associated with each cluster is a linear combination of the variables in the cluster, which may be either the first principal component or the centroid component. Then, each cluster can then be treated as a subtest, with the subtest scores given by the cluster components. If the cluster components are centroid components of the covariance matrix, each subtest score is the sum of the item scores for that cluster. The procedure can be performed either with explorative (as in variable cluster analysis) or confirmatory (as in Multiple Group Factor Analysis) purposes. The latter approach was employed for testing Salovey and Mayer's model on data from two independent samples. A comparison with models with a like number of components defined, respectively, by item means, standard deviations, skewness, kurtosis, and cluster random assignment was performed. Variance accounted for was higher for the hypothesized model, but exploratory analyses showed that better fitting models could be found and could show higher measurement invariance. Such results shed an additional eerie light on EIS psychometric properties but showed that VARCLUS procedure can be a valid alternative to PCA, EFA and CFA when a hierarchical structure among items is at issue.

**Keywords:** Psychometrics, emotional intelligence, multiple group factor analysis

## Visual-Auditory Integration in Saccadic Reaction Time: Recent Results

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Saccadic reaction time (SRT) to a visual target tends to be faster when an auditory stimulus is presented in close temporal or spatial proximity, even when subjects are instructed to ignore the accessory input (focused attention task). The time course of SRT as a function of stimulus-onset-asynchrony (SOA) is consistent with the time-window-of-integration (TWIN) model (Colonius & Diederich JCogNeurosci04) assuming a peripheral stage of parallel processing in separate sensory channels followed by a secondary stage of multisensory integration.

Several auditory localization studies suggest that the amount of SRT facilitation decreases not with the physical but with the perceivable distance (tested in a separate condition) between visual target and auditory accessory. Steenken et al. (Brain Res07) presented an additional white-noise masker background of 3s duration. With increasing masker level, SRT slowed down for spatially coincident visual-auditory stimulus pairs, whereas it was sped up with disparate stimuli. These results are accounted for by assuming a spatial blurring of auditory stimulus positions by the masker. Within the TWIN framework, the effects of the noise background on visual-auditory interaction are described by a modulation of the second-stage processing parameters only.

**Keywords:** Multisensory integration, saccadic reaction time, time-window-of-integration model

## Logic of Determination of Objects and Treillis de Galois

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There are three major formalisms that are developed around concepts. The first one is Formal Concept Analysis (FCA) by B. Ganter and R. Wille (Ganter and Wille, 1999). The second formalism is Description Logic (DL) developed during the 1980s for knowledge representation (Baader et al.2003). The third is Logic of Determination of Objects (LDO) by J.-P. Desclés originating in the 1980s in order to define and articulate notions as concepts and objects, to define and formalize a theory of typicality and an extended theory of quantification (Desclés 1980, 2002; Desclés & Guentcheva 2000; Desclés & Pascu 2006). LDO is a logic applied in natural language processing (NLP) and to the study of natural inferences in common reasoning. In all these formalisms, the notion of property is central. But Logic of Determination of Objects (LDO) is a new formalism about objects and concepts. It is a logic of objects and concepts developed in the framework of Curry's combinatory logic.(Curry & Feys 1958; Curry et al. 1972) Another formalism developed about concepts is the well-known Formal Concept Analysis (FCA). It is developed as an extension of algebraic Lattice Theory, namely Galois lattices. The Galois lattice as mathematical structure represents a Lattice Theory model of FCA. In our paper (Desclés & Pascu, 2007), we made explicit relations between LDO and FCA by constructing three variants of FCA motivated by LDO. In this paper we show why the Galois lattice is insufficient as mathematical model to modelise the typicality as part of the LDO.

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## The Time-Window-of-Integration (TWIN) Model: A Framework for Crossmodal Interaction

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Saccadic reaction time (SRT) to a visual target tends to be faster when an auditory and/or somatosensory stimulus is presented in close temporal or spatial proximity, even when participants are instructed to ignore the accessory input (focused attention task). The time course of SRT as a function of stimulus-onset-asynchrony (SOA) is consistent with the time-window-of-integration (TWIN) model (Colonus & Diederich JCogNeurosci2004) assuming a peripheral stage of parallel processing in separate sensory channels followed by a secondary stage of multisensory integration.

TWIN has been extended and tested in a variety of ways: it accounts for effects of the spatial configuration of the stimuli (Diederich & Colonus PercPsychophys2007), for the effect of increasing the number of nontargets presented together with the target (Diederich & Colonus ExpBrainRes2007), for the warning effect occurring with large negative SOAs (Diederich & Colonus ExpBrainRes2008), for some effects of aging on multisensory integration (Diederich, Colonus & Schomburg Neuropsychologia2008), and for effects of increasing the intensity of the nontarget (Diederich & Colonus BrainRes2008). There is support for TWIN's central assumption of separability between spatial and temporal effects on multisensory integration, independent of specific distributional assumptions for the peripheral latencies. The TWIN model can also be extended to account for data from divided attention tasks.

This talk will highlight some of the predictions and recent model testing results concerning the time-window-of-integration framework.

**Keywords:** Crossmodal interaction, multisensory integration, saccadic reaction time, time-window-of-integration model

## Semiorder Representations and Total Dual Integrality

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All representations of a given semiorder form a convex polyhedron—when they are suitably defined. The facets of the representation polyhedron correspond to the noses and hollows of the semiorder (the notions of noses and hollows are due to Pirlot, 1990, 1991 and are reconsidered by Doignon and Falmagne, 1997). On the other hand, our control of the vertices of the polyhedron still remain unsatisfactory: in particular, we would like to fully understand how the vertices are related to the structure of the given semiorder. Although the main problem about vertices remains open, we are now able to show that all vertex coordinates are integer multiple of a fixed real number and to establish even deeper properties of the representation polytope. These properties follow from the total dual integrality of the system of linear inequations which define representations. In turn, total dual integrality derives from a combinatorial property of the digraph of noses and hollows. The property is akin to the notion of 1-discrepancy for graphs due to Gerards (1994).

This is joint work with Bary Balof (Whitman College, Walla Walla) and Samuel Fiorini (U.L.B.).

**Keywords:** semiorder, semiorder representation, nose, hollow, total dual integrality

## Perceptual Discrimination: Old Problems and New Perspectives

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The talk will touch on a spectrum of theoretical issues and problems related to same-different and greater-less judgments. Among the issues are those of subjective identity of stimuli, matching of stimuli across observation areas (the law of Regular Minimality), the notion of perceptual closeness (perceptual topology and uniformity), and the computation of subjective distances from discrimination functions (Fechnerian Scaling). The problems to be discussed include a pairwise-comparison version of the ancient sorites paradox, according to which a series of stimuli can be formed in which any two successive stimuli are not discriminable while the first and the last one are; and the fact, seemingly refuting Fechner's theory, that the number of just-noticeable differences between isosonic curves is different at different tone frequencies. The talk will present a generalization of the law of Regular Minimality to multiple observation areas (required, among other things, for dissolution of the sorites paradox). Time permitting, the possibility of topological and metric computations which are not based on Regular Minimality will be discussed too.

## On meaningful scientific laws on bounded domains: A theoretical analysis

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Scientific laws are commonly formulated for variables taking their values on the positive reals, that is, on domains which have no upper bound. This is the case for the laws of classical physics, and also in many psychophysical situations. In the latter case, the existence of positive lower bounds induced by the existence of thresholds is also often ignored. Weber's Law, the Near-miss-to-Weber's-Law and Stevens's Power Law for magnitude estimation or magnitude production data are well-known examples. To be sure, the rule of ignoring the existence of bounds in formulating scientific laws is not universal. In special relativity theory, the postulate that the speed of light has an upper bound of 299,792.458 m/sec is a famous exception. In psychophysics, bounded versions of Weber's Law, with a positive threshold and an upper limit are sometimes postulated, and implemented by adding constants in the expression of the law. However, the introduction of bounds modifying the expression of a law is not systematic. It is rather, typically, made on the basis of particular considerations, by adding a constant here or there. This is not satisfactory. The values of upper and lower bounds of variables that can be used for stimuli in a psychophysical situation are important parameters that should not be ignored or treated casually in the formalization of models. This paper is a first pass at a general approach, in which the possible forms of scientific laws for bounded domains are derived from general principles, including in particular meaningfulness. An application to the size-weight illusion is described.

## Decomposing “lawlikeness”

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Is a theory “applicable to all kinds of reasoning under uncertainty” (Grünwald 2000:133) conceivable in view of the problems discussed in the philosophy of science? Most models of model selection are two-dimensional, balancing e.g. “empirical adequacy” against “integrative generality” (Laszlo 1972:388), power against generality (Coombs 1984), or parsimony against goodness of fit (Forster, 2000:205). Coombs’ model requires, to my opinion, a completion by parsimony as a third dimension. Are such criteria of theory assessment, in self-referential ways, also applicable to the theory of theory assessment? This is exactly what I will try here, focusing on the key concepts of “law” and “lawlikeness”. In Goodman (1973:90, 108) a hypothesis is lawlike and projectible if it is supported (some positive cases), unviolated (no negative cases), and unexhausted (some undetermined cases). But especially the criterion “unviolated” rather applies to universal laws (Fenk & Vanoucek 1992:24). In the philosophy of science we see a shift from the universal laws in the Deductive-Nomological model by Hempel & Oppenheim (1948) and the statistical arguments rendering probabilities “close to 1” to the explanation in Hempel’s (1962) Inductive-Statistical model to the reduction of “plausibility” to relative frequencies (Mises 1972:114) and to “stable” frequency distributions as a sufficient basis for “objective chances” (Hoefer 2007). Carried to the extremes: If a dice produced an uneven number in ten of fifteen cases I would, if I had to bet, bet on “uneven” for the 16th trial. For if there is a system it seems to prefer uneven numbers, and if there is none, I cannot make a mistake anyway (Fenk 1992:36). Thus I would also bet on “uneven” if this was the output of a one-trial-“series”. Hardly anybody would talk about relative frequencies, let alone laws, in these examples or in the case of a series of ten S1S2 combinations in a conditioning experiment. But these examples reflect a principle as simple as general: Use the slightest indication and all your contextual knowledge to optimize your decision and bet on continuity unless you make out indications that a system might change its output-pattern; generalize the patterns observed and project them to unknown instances! “Laws”, “probabilities”, and “objective chances” are persuasive names for such generalizations. But there is, as Hempel (1968:117) had to admit in principle, no lower bound regarding the strength of a regularity or the number of data available that ceases the admissibility of this way of inductive reasoning. !

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**Keywords:** Reasoning under uncertainty; inductive inference; model selection; relative frequencies; laws

# The Use of Meditation in Learning–Teaching Processes of Mathematics

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A methodological hypothesis that explores the psycho-pedagogical aspects underlying models of learning-teaching, within the framework of the psychology of teaching Mathematics, is proposed. The results of a project, made by the study center “Frontiere del possibile”, on the use of Meditation in the improvement of the learning processes at the level of school students are presented.

The research investigates the way children and young boys learn, trying to focus on the main barriers of the learning process, and tests some methodological strategies to improve the quality of the teaching. A part of the work has been specifically devoted to the learning of mathematical concepts [1-3], that, according to recent statistics on students’ learning and performance [4], are among the most complicated subject to understand and teach in Italy. The close link between the cognitive and emotive components, mediated by peculiar anatomic and physiological structures, such as the amygdala, is stressed.

It is suggested that one of the most common block of the learning process lies in the poor consideration of the emotive component. This can negatively affect the personal experience of the student, together with the construction of the Self in relation with the concept of knowledge. In addition, it creates huge obstacles in the learning process, negatively perturbing the fundamental skills of Memory, Attention, Motivation and Listening.

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**Keywords:** Mathematical Learning, Meditation

## Children learn with gestures

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It is known that learning scientific concepts is often difficult for the students. These difficulties are related to both the intrinsic complexity that specific concepts have, and to functions they represent compared to the subject. In this case the students have a certain difficulty to identify the geometrical or mathematical properties of an object. These limits do not allow them to understand the structural and mathematical properties. Usually, the transmission of scientific knowledge is done mainly through two codes: visual-spatial and verbal. The use of these two codes work well until the student is able to represent mentally the structure of the object and identify the mathematical and geometric properties. Conversely, when the subject is asked to start a process, as abstraction, then the verbal and visual codes seem not enough. Both codes need another code: the gestural one. Recent research (Arzarello, 2007; Broaders et al., 2007; Goldin-Meadow, 2003; Goldin-Meadow and Alibali, 2002; McNeill, 1992), show that the gestural code has a key role in learning mathematical concepts. For example, the rotation movement of an object (e.g. cylinder, cone, and so on) implies that it has a spherical shape and its properties can be explored from many sections. In fact, the act of rotation of the object also includes the abstract idea of circularity and sphericity. The rotation behavior is codified in relation to the exploration movement of the object in order to improve the conceptual representation of its mathematical and geometric properties. The gesture, along with language, supports the verbal and visual codes, thanks to a mechanism schematic representation of the concepts, based on the body. In this paper we present the results of a research carried out with middle school students whose goal was to analyze the role of gestures during “problem solving” mathematical activity. The subjects have worked in a problem solving context, during which they were recorded for later analysis. The method of analysis includes three phases: 1) design of behavioural taxonomy; 2) evaluation of taxonomy; 3) analysis of the behavior gestural uses the software Noldus Observer XT 7.0. Initial results indicate that the gesture improves both the generation of the new concepts, expressed using the visual and verbal code, as well as the collaboration between students because gestures improve the exchange of ideas. Moreover, even

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when using tool the subjects need to use gestures to make better and more explicit the concepts needed to solve the problem assigned to them.

**Keywords:** Gesture, Problem-solving, Observation method.

## Comparative performance of several setup options in a concurrent common-item equating design involving Likert-type items

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Current interest in measuring quality of life in the medical and social sciences is drifting towards the construction of adaptive tests with Likert-type items. Calibration of an item bank for use in computerized adaptive testing requires collecting responses to a large number of candidate items, a number that is usually too large to administer to each subject in the calibration sample. To solve this problem, strategies like the concurrent common-item equating design have been proposed, a strategy consisting of (1) splitting the total number of  $N$  items into  $n$  separate sets (the subtests) with  $c$  common items across subtests, (2) administering each of the  $n$  subtests to a different sample of subjects from the target population, and (3) running estimation software once on the aggregated data sample, in which a substantial number of responses are structurally missing by the design. Although the use of concurrent common-item equating designs is widespread, it appears that the consequences of several design decisions on the accuracy of parameter estimates have never been studied in the polytomous case. We address this question by simulation, comparing the outcomes (in terms of the accuracy of parameter recovery) of several alternatives for the configuration of the equating design. Only Likert-type items on a five-point scale under Samejima's graded response model are considered in this work. The factors defining variants of the equating design are: (1) subtest size (15 vs. 20 items), (2) balance of common and unique items per subtest (e. g., 5 common and 15 unique items vs. 15 common and 5 unique items in 20-item subtests), (3) discriminative power of the common items (i. e., maximal, minimal, heterogeneous, or randomly chosen), and (4) distribution of unique items across subtests (quasi-parallel vs. at random). The results indicate that maximizing accuracy in item parameter recovery requires subtests of the largest number of items that is feasible with the fewest possible number of common items, whereas the characteristics of the common items and the criterion for distribution of unique items do not seem to make any difference.

**Keywords:** Test equating, Likert-type items, simulation, Computerized adaptive testing

## The Rasch Model: Comparison between Rumm, Winsteps, and Logistic Regression Approaches

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In the Rasch model the item response is a function of two independent parameters: the subject ability and the item difficulty. By means of the logit transformation the relation between the response of the subject to the item becomes linear and expressed by the formula:  $\text{logit}(\text{response}) = \text{ability} - \text{difficulty}$ . The two parameters of the model can be analyzed by special programs, such as Rumm and WinSteps, or by a general procedure like the Logistic Regression. The aim of this work is to compare the results obtained by the different approaches. A data set of the responses to 15 dichotomic items measured in a sample of 70 subjects is used. The same data set is analyzed by the Rumm software, WinSteps program and a Logistic Regression by means of the SPSS statistical package. In order to analyze the ability and difficulty parameters by means of the Logistic Regression, each response of each subject is considered as a case. In this way the sample consists of 15 by 70 cases. As categorical covariates of the logistic model the ability and difficulty are used. The results show different values for the estimated parameters obtained by the three approaches. The WinSteps parameters are strongly correlated to that evaluated by Logistic Regression. Using the ability and difficulty parameters, the estimated responses are evaluated for each procedure. The misclassification tables are then used to compare the efficiency and the features of the three methods.

**Keywords:** Keywords: Rasch model, item response theory, logistic regression

## A Model of the “Game in Location”

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The purpose of the present work is a research of coalition game with a few beforehand fixed coalitions, and also coalition game with possibility of entrance and return of players from coalition. Rules designed psychological mechanisms, such as motivation, acceptance itself and social activity, are offered. Let's give determination of a game in location. In such kind of a game  $K$ -players participate, each of which can choose in every party of a game one action from possible  $M$ . The size of memory is an amount of choices. The game is determined by a set of winnings. We consider that in the coalition variant of game in location total winning is divided between the members of coalition. Participation in a game in location for the automats is a functioning in a stochastic environment. The followings cases are compared for the same set of probabilities (winnings): game without coalition of  $K$ -automats; coalition game, when all automats are incorporated in one coalition; coalition game of  $K$ -automats with a few fixed coalitions; coalition game of  $K$ -automats with possibility of formation of coalitions and exit from them in accordance with some rules. An imitation design is conducted for the concrete set of probabilities “ $P$ ”. Computational experiment showed that the automats changed their actions in comparison with the theoretical situation. Also we first consider the case of formation of coalitions during a game. The following rules are accepted. If the individual winning less, than coalition winning for the fixed time, a player enters into a coalition with some probability “ $A$ ”. If theoretical individual winning on leaving from coalition is more, than actually middle winning got in coalition, a player goes out from coalition with some probability of “ $B$ ”. The limited values of winning were compared for different variants. 1. The maximum winning depends on the size of memory, both for an individual game and for a game with one fixed coalition, uniting automats on principle of “total profit”. 2. At all values of volume of memory there is the maximum winning of every player, included in coalition more than maximum winning of individualists. With growth of volume of memory the distinction in the maximum winning of automat, included in coalition and individualists, grow. 3. For the case, when some players are included in coalition, and others play individually, the last get the considerably greater winning.

**Keywords:** game in location, stochastic automat, coalition, automat-individualist, limited values of winning

# A three-state three-trait Axelrod model for language choice dynamics

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In the standard Axelrod (1997) model of social interaction,  $N$  agents are considered as the sites of a network. The state of agent  $i$  is a vector of  $F$  features  $(\sigma_{i1}, \sigma_{i2}, \dots, \sigma_{iF})$ , where each  $\sigma_{if}$  can take any of the  $q$  integer values (traits)  $1, \dots, q$ , initially distributed independently and with equal probability  $1/q$ . The internal dynamics of the model is driven by the following iterative steps: (1) A pair of sites of the network connected by a link  $(i, j)$  is randomly selected, (2) the number of overlapping features  $l(i, j) = \sum_{f=1}^F \delta_{\sigma_{if}, \sigma_{jf}}$  is calculated, and (3) if  $0 < l(i, j) < F$ , the connection is said to be active and sites  $i$  and  $j$  interact with probability  $l(i, j)/F$ . In case of interaction, we choose  $g$  randomly such that  $\sigma_{ig} \neq \sigma_{jg}$  and set  $\sigma_{ig} = \sigma_{jg}$ .

In the present paper, we expand our previous voter model of language choice dynamics (Hadzibeganovic, Stauffer, & Schulze, 2008) into a modified three-state three-trait Axelrod-type model. The Monte Carlo simulations are motivated by states with a linguistically homogeneous but politically divided population, consisting of three groups of various affinities to each other. Starting with this ternary initial configuration, computer simulations are conducted for different lattice sizes, different amounts of outside pressure, and asymmetric internal noise distribution. We investigate the influences of age, wealth and political conviction of individual decision makers on the global opinion dynamics, resulting in a strong fluctuating behavior of all three populations but still close to their initial values. We demonstrate that the global polarization of language choices can persist in spite of a dynamics of local convergence. In addition, we assume that a random (quenched) fraction of population never changes its opinion during a simulation. Furthermore, a number of "rigid-minded" decision makers might just "tune-out" (Hsu, Regenwetter, & Falmagne, 2005) from changing their order of preferences at one or several points in time, thereby considerably affecting the overall evolution of opinions. The density of never changed opinions since the start of the simulation was found to decay initially as about  $1/t^{0.4}$  for  $t < 10^3$ , and then stronger down to zero. This power law differs from the behavior of other opinion dynamics models with different noise or without noise (e.g., Ben-Naim, Frachebourg, & Krapivsky, 1996; Drouffe & Godreche, 1999). Finally, we discuss how the presented model can be generalized within the context of

Hopfield neural networks with up to  $10^8$  nodes (Stauffer, Grabowicz, & Holyst, 2008).

**Keywords:** Monte Carlo simulation, opinion dynamics, language choice, agent-based model, language competition, networks.

## Empirical Validation of Knowledge Structures: A Resampling Perspective

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Evaluating the empirical validity of knowledge structures for a given set of data is to be based on statistical decisions. Most of the proposed measures of goodness-of-fit, however, are ad-hoc indices that do not come along with sound statistical procedures for their evaluation. Resampling techniques provide a general framework for solving this problem. Any application of these methods, however, requires to have available a characterization of the complexity of a knowledge structure. The talk explores conceivable notions of complexity and considers their impact for implementing a trade-off between goodness-of-fit and model complexity within resampling tests of the empirical validity of knowledge structures.

**Keywords:** Knowledge Structures, resampling tests, model complexity

# The Effect of Sample Size Ratio on the Power and Type I Error of the Mantel-Haenszel in the Detection of Differential Item Functioning

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The Mantel-Haenszel (MH) statistic, originally proposed by Mantel & Haenszel (1959) in the field of epidemiological research and subsequently used by Holland & Thayer (1988) to detect differential item functioning (DIF), is nowadays one of the most popular procedures in studies of bias in psychological tests with dichotomous-items. Due to its mathematical simplicity and low computational cost, the MH procedure quickly became popular and, as a consequence, a significant amount of research over the last twenty years has aimed to analyze the effect of various factors on its power, distribution and Type I error. The present study examines the effect of the reference/focal group sample size ratio (number of persons of reference group for one person of focal group) on the power and Type I error of the MH procedure in detecting uniform, nonuniform and mixed DIF in dichotomous items. Method: With simulated data, we did a completed crossed factorial design for 168 conditions, product of five factors manipulated: sample sizes (1000, 2500 and 5000), sample size ratios (1, 3, 5, 10, 15, 20 and 25), impact (yes or no), test length (20 items and 40 items) and DIF percentage (0 and 15%). Each condition was replicated 1000 times. We used the EZ-DIF software for detection of DIF with MH statistic and we analyzed statistical values with  $p < 0.05$  and  $p < 0.01$ . Results: The type I error is smaller in conditions with largest sample size ratio, small sample size and there is not impact; however there are not clear results regarding the effect of the test length and the DIF percentage. Regarding the power, it was found that it is higher for small sample size ratio, large sample sizes and in tests with a high DIF percentage for all the DIF types. As relevant results it was observed that there was an improvement in the detection of nonuniform DIF when the samples were large, there was an impact and a high DIF percentage. In general terms, the detection rates were generally higher for items with uniform DIF and considerably lower for items with mixed DIF. Discussion: These results show the utility of the MH for the DIF detection in small samples, at least of 1000 examined; however the nonuniform DIF detection demands the use of

large samples. Finally, the discussion of these results in terms of the discrimination and difficulty of the items is outlined as a possible extension of this work.

**Keywords:** Mantel-Haenszel, sample, size ratio, differential item functioning, Type I error, power

## Real-Time Skill Assessment

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Over the last 15 years, the focus of applying knowledge space theory has moved from adaptive testing to personalised learning. More recently, research on technology enhanced learning seeks to introduce new pedagogical approaches like game-based learning and learning through complex problem solving and simulations. This leads to new ways for assessing the learners' knowledge and poses new challenges for applying knowledge space theory in this area.

Competence based knowledge space theory has been successfully applied in the context of game-based learning. The basic underlying idea is to interpret the learner's observed behaviour with respect to the underlying skills and to perform a skill assessment on the skill space based on this interpretation.

Contexts like learning games, however, put special requirements onto the assessment in this area: the skill spaces are often rather large, observation-based evidence may come at a high frequency, and assessment has to be performed in real-time in order to ensure an undisturbed game-playing.

As a solution, a temporal usage of sub-spaces is proposed. Within a certain learning situation, we normally obtain evidence only for a small subset of skills. Performing skill assessment during such learning situation only on the trace of the skill space can strongly support keeping the real-time requirement. It is shown that this assessment on the trace of a skill space leads to results equivalent to an assessment on the complete skill space.

**Keywords:** Competence based Knowledge Space Theory, personalised learning

## Dual - Channel Model of Frog's Achromatic Vision

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The research of achromatic vision in frogs was conducted by a registration of an electroretinogram (ERG) as response to abrupt change of one achromatic (or chromatic) stimulus to another one (silent substitution technique). The amplitude of a b-wave in ERG was considered as the overthreshold measure of difference between stimuli. Four (red, green, blue and white) set of stimuli of different intensities were used in experiments. For each set of stimuli the collection (matrix) of ERG amplitudes as responses to pair wise dissimilarities between stimuli was obtained. These data were processed by multidimensional scaling technique. MDS analysis of dissimilarities among chromatic and achromatic lights varying in luminance shows that if these dissimilarities are interpreted as directly related to Euclidean distances, then the color points form a two-dimensional geometric configuration. An essential feature of this configuration is that the points do not fill in the two-dimensional space densely, but rather form a smooth curve, which is a half of a circle. The positions of the points on this circle are characterized by spherical coordinates corresponding to variation of luminance detected by frog's retina. The obtained results allow to consider achromatic vision of a frog in the terms of the dual-channel neuronal network. This model is similar with two-dimensional models of achromatic vision in human obtained by psychophysical methods and by method of evoked visual potentials.

**Keywords:** Bootstrap, EEG, S-Plus

## Modeling an Environment to Facilitate Creativity

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Creativity is a phenomenon typically interpreted as a stable attribute possessed by a particular focal system such as a person, product, process or an environment. Whether and to which extent a focal system features creativity is commonly assessed by measuring its output in terms of quantity, originality and usefulness. The latter both are scientifically accepted attributes of creative products. This distinction indicates two underlying processes involved in assessing creativity: production and evaluation.

From a systems perspective, investigating creativity is not based on assumptions of constant system characteristics. Instead, creativity emerges via interaction between creator and observer. Moreover, the emergence of creativity can systematically be explored in terms of a) creators producing output within a particular environment and b) evaluators judging these outcomes according to their originality and usefulness. Csikszentmihalyi (1999) developed a systems model of creativity which heuristically describes these production and evaluation processes. His relational approach is based on the interaction between three social systems: individual, field and domain. The field, a part of society, and the domain, a part of culture, constitute an individual's environment. The individual is characterized by two variables, *personal attributes* and *motivation*, and the field is primarily characterized by three variables: *resources*, *institutionalization*, and *autonomy*.

In this presentation, an agent-based simulation to test the relations assumed in this heuristic model will be introduced. An environment symbolized by different extents of resources, autonomy and institutionalization surrounds "creators" characterized by different levels of personal attributes and motivation. "Evaluators" observe creators' output and judge it according to a creativity definition based on subjective frame of reference. Translating this heuristic systems model of creativity requires programming several functional dependencies currently derived according to their face validity: a) the separate influences of resources and institutionalization on creative production, b) their combined influence, c) the influence of personal attributes on creative production, d) a motivation function, e) an evaluation function for judging artifacts, and most importantly f) a formalized definition of creativity. The presentation will depict the theory's translation into an agent-based model, and open a discussion about derived face valid functions for the underlying processes and interactions.

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**Keywords:** Creativity, agent-based modeling, systems theory, social system

## Interval scales modelling in drawn projective techniques

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In the present research project possibility of interval scales modeling in drawn projective techniques is shown. Increasing psychological measurement accuracy, as it is well known, is connected with strong measuring scales modelling. It is considered in psychodiagnosics that results of drawn projective techniques based on the theory of psychomotor bonds, which use reflection of individual psychological characteristics of the probationer of graphic activity in the results of this activity, basically cannot be shown in strong scales. In the present research possibility of such modelling is shown by the example of studying unconscious components of demonstration of personal aggressiveness.

Personal aggressiveness and its manifestation in behaviour, aggression, belong to the field under long-term and successful psychological research. However the question about accuracy and validity of techniques diagnosing aggressiveness demonstration rises before researchers again and again. For the purpose of diagnosing aggressiveness in the process of the present research work it was offered to the probationers to draw a nonexistent animal on a white blank A4-size sheet of paper and a person on another sheet. In practical manuals to drawn projective techniques the results of the analysis are presented only in the form of description; the degree of aggressiveness is expressed with the number, location, and character of corners in the drawing, irrespective of their connection with any image detail. Direct symbols of aggressiveness: claws, teeth, beaks, are especially important in this respect. Various kinds of aggressiveness are shown in the drawing differently (verbal aggressiveness - teeth, physical - claws, instruments of attack, etc., protective - intension to protect with shell, scales, and thick skin). Having revealed the qualitative attributes of demonstration of different kinds of aggressiveness in drawings of nonexistent animals and persons, for receiving primary parameters of aggressiveness we have modelled 8 ordinal scales of identical format (from 0 up to 2 points). Aggressiveness attributes in the drawing of nonexistent animal were put into 5 categories (zones): mouth, additional attributes of aggressiveness, sharp edges in contour, aggressive symbols and instruments of attack, and protective elements; in the drawing of person such categories are: face, hands, and aggressive accessories (including the image of blood).

With the purpose of standardizing of the received information the qualitative analysis of the drawings has been extended by quantitative means of implementing the scale of aggressiveness. The "row" characteristics of aggressiveness are calculated by adding results of each diagnostic attribute within the limits from 0 up to 16 points.

For carrying out quantitative analysis (in particular, correlation analysis) the "row" drawn points need to be re-counted in an interval scale. The issue has been considered for youth

based on the results of work with representative stratified random number of probationers (633 persons), consisting of senior pupils, students of colleges and higher schools. With this purpose percentile normalization has been accomplished, and it allowed to receive interval z-estimations reflecting levels of the phenomenon under consideration.

**Keywords:** psychological measurement, interval scales, unconscious components of aggressiveness, drown projective methods, aggressiveness scale, percentile normalization

## Measuring change using item response models: A comparison of different approaches

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The Item response models for measuring change offer interesting possibilities especially for analyzing item-specific intervention effects. Glück et al. (2005) tested effects of two different types of trainings on performance in a battery of spatial tests including the Mental Cutting Test (MCT, College Entrance Examination Board, 1939). On the score level, there were marked general retest effects, but no differences in treatment effects between groups. In the present study we analyse changes in MCT performance based on the identification of homogeneous item subgroups. Item response models for longitudinal research – i. e. linear logistic test model (LLTM), linear logistic model with relaxed assumptions (LLRA) and mixed Rasch-model (MRM) were used to test differences in change between item and participant subgroups. The results show differences in treatment effects between subgroups of items. General suggestions for item-level analyses of change with non-homogeneous test materials are given in the discussion.

## Adaptive estimation of the parameters of Luce's choice model

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We present a simple but effective method based on Luce's (1959) choice axiom for consistent estimation of the pairwise confusabilities of items in a multiple-choice recognition task with arbitrarily chosen choice-sets. The method combines the exact (non-asymptotic) Bayesian way of assessing uncertainty with the unbiasedness emphasized in the classical frequentist approach.

We apply the method to data collected using an adaptive computer game designed for prevention of reading disability. A player's estimated confusability of phonemes (or more accurately, phoneme-grapheme connections) and larger units of language is visualized in an easily graspable way with color cues and explicit indication of the accuracy of the estimates. Visualization of learning-related changes in the player's performance is considered.

The empirical validity of the choice axiom is evaluated using the game data itself. The axiom appears to hold reasonably well although a small systematic violation is observable for the smallest choice-set sizes.

**Keywords:** Confusion matrix, multiple-choice task, choice axiom, constant-ratio rule, learning game, grapheme-phoneme connection, dyslexia, adaptive estimation, Bayesian statistics, Markov Chain Monte Carlo, Rao-Blackwellization, minimum variance unbiased estimator.

## Modeling the perception of binocular 3-D motion direction

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Humans have two eyes that are set a short distance apart so that an extensive region of the world is seen simultaneously by both eyes from slightly different points of view. Vision in this region of binocular overlap has a special quality that has intrigued philosophers, artists and scientists. Although the image of the world thrown onto the retina of the left and right eye is essentially 2-D we vividly see the world in 3-D. This is true for static as well as moving scenes but characteristics of binocular 3-D motion processing are generally different from stereo vision. The early stages of motion and stereo processing in the human visual system are relatively well understood. There is widespread agreement that early spatio-temporal encoding relates to the processing of motion (Smith & Snowden, 1994) whereas disparity encoding relates to the processing of depth (Howard & Rogers, 2002). How the visual system effortlessly establishes a 3-D motion percept from motion and disparity input remains an unsolved problem.

Some promising Bayesian models have been developed in computational vision. Most notably Weiss, Simoncelli and Adelson (2002) combined motion constraints of local motion detectors with a Gaussian velocity prior to predict perceived velocity of luminance-defined stimuli in 2-D space. With this elegant approach they could explain a range of previously unrelated 2-D motion illusions. Here we extend their approach to binocular 3-D motion perception. If we assume that the human visual system solves the inverse problem of 3-D motion similar to Bayesian inference then local image constraints are combined with a prior for slow motion to arrive at the most likely interpretation for perceived 3-D motion direction (Lages, 2006). Using inverse geometry and simple statistical arguments we derived predictions for stereo and motion processing under uncertainty. In psychophysical experiments on dot and line stimuli we compared model predictions with perceived motion direction. The results suggest that under uncertainty perceived 3-D motion direction is systematically influenced by a prior for slow motion in a 3-D world. We discuss implications of these findings on the functional architecture of binocular 3-D motion processing.

**Keywords:** Bayesian models, 3D motion, binocular motion, disparity, model selection

## Free Recall: A resuscitation of the Total Time Hypothesis

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The Total Time Hypothesis says that the mean number of words recalled in single-trial free recall depends only on the total time taken to present the list of words, and not otherwise on the length of the list or the rate at which it was presented. On the basis of a large and careful experiment Roberts (1972) concluded “Recall for equated lists [Length  $\times$  seconds/word = Total Time] was greater the longer the list and the faster the rate of presentation.”

This paper revisits Roberts’ data from a different perspective. Development of the martingale model presented at the EMPG meeting in Padua, 2005 (Laming, 2005), leads to a revised formulation of the total time hypothesis that conforms with Roberts’ data. This revised formulation says that it is  $-\ln(P)$  (no recall at all) that depends on the total time of presentation. It differs mathematically from the version that Roberts tested solely in a matter of approximation. Let  $\pi_j, j = 1, \dots, N$ , be the probabilities of recalling the individual words in a list of length  $N$ . The probability of not recalling anything at all is  $\prod_{j=1}^N (1 - \pi_j)$ . The revised version of the hypothesis focuses on the sum  $-\sum_{j=1}^N \ln(1 - \pi_j)$ , while Roberts examined the function  $\sum_{j=1}^N \pi_j$ , which is the expected number of recalls.  $p_j$  is, of course, an approximation to  $\ln(1 - \pi_j)$ , accurate for small  $\pi_j$ . A further analysis aligns separate divisions of Roberts’ data for auditory and visual presentation of the words and suggests a reason why auditory presentation is superior.

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Roberts, W.A. (1972). Free recall of words lists varying in length and rate of presentation: A test of the total time hypothesis. *Journal of Experimental Psychology*, 92, 365–372.

**Keywords:** Free recall, Martingale model, Total time hypothesis

## Minimal covering set solutions

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We study necessary and sufficient conditions for a multi-valued solution  $S$  to be rationalized in the following sense: there exists a complete asymmetric relation  $T$  (a *tournament*) such that, for each feasible (finite) set, the solution set of  $S$  coincides with the minimal covering set of  $T$  restricted to that feasible set. Our characterization result relies only on properties relating  $S$  across feasible choice sets.

## Modelling pitch perception of Shepard stimuli

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Pitch perception of Shepard-stimuli is characterized by a couple of well known properties such as intransitivity (circularity) and ambiguity (Shepard, 1964). Closely related phenomena include the so-called tritone-paradox (Deutsch, 1991), semitone-paradox (Deutsch, 1988), and spectral envelope and context effects (Repp, 1997). It has been investigated with respect to speech production (e.g. Deutsch, 1997), perceptual dynamics (e.g. Giangrand, Tuller, and Kelso, 2003), or spatial representation (e.g. Lidji, Kolinsky, Lochy, and Morais, 2007). A unified model, however, is still missing.

In our talk we present results of experiments with complete pair comparisons of Shepard stimuli as well as matchings of Shepard stimuli with simple sinusoids. Various scaling models are discussed with respect to their ability to represent the results as well as the above mentioned phenomena.

**Keywords:** Pitch perception, Shepard stimuli, Intransitivity scaling, Tritone paradox

## Using IRT-Models to detect and quantify position-effects in psychological tests: Pitfalls and possibilities

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Within the context of psychological tests, symptoms of fatigue or training effects can occur, i. e. the items' *conditional* difficulties vary contingent on their actual position within the test instrument. Formally put, the conditional difficulty ( $\sigma_{ip}$ ) of an item  $i$  at a position  $p$  is the result of its unconditional difficulty and the position's influence ( $\beta_i + \omega_p$ ). The present study investigates and quantifies position effects using a Rasch-homogenous computer-based reasoning test (Begriffsbildungstest – BBT; Kubinger, Fischer & Schuhfried, 1993; Alexandrowicz, 1999). The test was reprogrammed with 12 items from the original pool in 12 permutations (latin square design) and administered to a sample composed primarily of students at the University of Klagenfurt.

Following the suggestion of Alexandrowicz and Matschinger (2008), parameters for item difficulties and position effects were estimated using the linear-logistic test model (LLTM; Scheiblechner & Fischer, 1972; 1973) reformulated as a generalized linear model (random intercept model with a logit link and binomial error; see for example De Boeck & Wilson, 2004).

In the first test wave, only permutations A (Items 1 through 12) and I (Items 9 through 12 and 1 through 8) were used, which lead to a set of collinearities. Because of the implemented regression approach, it is possible to predict collinearities (by merely investigating the respective predictors) and thus avoid such problematic combinations of groups. A way to compute ordinary least squares solutions for linear regression is through the matrix algebraic term  $(\mathbf{X}^T \mathbf{X})^{-1} \mathbf{X}^T \mathbf{y}$ . Once collinearities are present, the inversion of  $\mathbf{X}^T \mathbf{X}$  will fail, thus we can avoid this kind of pitfall a priori by checking for feasible combinations of groups.

These computations were generalized in R for  $k$  items and  $g$  realized groups and checked by means of simulation in Stata. The subsequent findings were used to refine the study's design and thus get more accurate parameter estimates.

The knowledge about position effects and the possibility of their quantification leads to benefits in the process of constructing and using adaptive psychological tests. (1) conditional item difficulties can be resolved into unconditional difficulties and position effects (2) when testing adaptively, one can appropriately merge these parameters again to bring

forth items with the highest possible information for the testee.

**Keywords:** Position effects, order effects, differential item functioning (DIF), item response theory (IRT), linear-logistic test model (LLTM), collinearity

## Discovering Structures in Mixed (Numerical & Categorical) Data Using Dimensional Analysis

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Previously introduced (Marinov, 2002) concepts of Dimensional Structure (DS) and Dimension-Like Structure (DLS) are described and discussed in detail. DS arises in applying physical Dimensional Analysis (DA) to a complete set of physical variables/constants relevant to a phenomenon under investigation. Within the framework of DA, firstly, such a structure always exists, secondly, it is uniquely and unambiguously determined by the dimensions of the variables/constants involved, and thirdly, it is established before resorting to data. DLS - an extension of the concept of DS - is defined as a structure of relations among any kind of quantities similar to those structures arising among physical quantities when DA is applied. Unlike DS, firstly, a DLS does not necessarily exist, secondly, multiple structures may co-exist simultaneously, and thirdly, the existence of such a structure is established in statistical sense upon applying a technique, referred to as Reversed Dimensional Analysis (RDA), to a particular data set (Marinov, 2002). It has been shown (cf. Marinov, 2004) that regardless of the nature of variables involved, any data set can be examined for the existence of a DLS, and that, if such a structure found, a dimension can be attributed to non-physical variables. It has been particularly demonstrated that such dimensions, referred to as phenomenological dimensions, allow for meaningful interpretation in psychophysics (Marinov, 2004). A recently proposed (Marinov, 2008) application of RDA in quantifying categorical data is also discussed. Theoretical basis and computational algorithms for such quantification are described, and results of computer simulations with model data of the kind  $z=f(x,y)$ , where one of the variables is considered categorical, are reported in support of the proposed approach.

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**Keywords:** Dimensional analysis, categorical data, quantification

## A Comparison of Unipolar and Bipolar Rating Scales for Measuring SWB

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**Introduction:** A review of the literature shows that most of scales for measuring satisfaction have a bipolar format. By using two-way bipolar scale we try to locate the studied construct (satisfaction) on a bipolar rating scale (with opposing satisfaction and dissatisfaction verbal end-points). This means, as the circumplex model of affect suggests, we have accepted the bipolarity of this adjective (satisfaction). To test the relationship between affective antonyms, Russell and Carroll (1999) argue that the two items must be measured separately using unipolar response formats. This is because bipolar response formats force bipolarity on the respondent with the nature of the scale implies the appearance of bipolarity in the data. Clearly this does not occur when using unipolar scales where the respondent is free to independently rate each affective antonym separately. The main goal of the current study was to determine whether or not the use of different response format, differing in polarity (bipolar versus unipolar), affect on (1) the overall life satisfaction and life dissatisfaction ratings, (2) the relationship between overall life satisfaction and life dissatisfaction rating, and (3) the relationship between overall life (dis)satisfaction and (dis)satisfaction with different domains of life.

**Participants:** A sample of 298 volunteering students randomly assigned to two different conditions, rated their current overall life (dis)satisfaction and their (dis)satisfaction with six different domains of life. Each condition used one of two rating scale formats, differing in polarity (bipolar versus unipolar).

**Materials and Procedure:** Overall life (dis)satisfaction and (dis)satisfaction in different domains of life, Physical health, Psychological well-being, Social relations, Leisure, Financial situation and Student life, were measured by a self-report rating scale contained a total of 14 items.

**Results:** Our results indicate that, the nature of response scales may influence the overall life (dis)satisfaction as well as the relationships between overall life satisfaction and life dissatisfaction ratings. Satisfaction ratings using with either a unipolar or bipolar response scale were similar. However, participants clearly experienced greater difficulty in rating life dissatisfaction using the bipolar dissatisfaction-satisfaction response scale. Participants were confused by the bipolar scale and appear to have focused on the satisfaction anchor of the bipolar scale, despite the items asking for dissatisfaction ratings. Moreover life satisfaction and dissatisfaction used to show a reciprocal relation with a high negative correlation when assessed with two independent unipolar rating scales, so using two independent unipolar rating scales are recommended for measuring overall life satisfaction and life dissatisfaction ratings.

**Keywords:** Overall life satisfaction-Bias-Rating scale- Bipolar scales-Unipolar scales

## A truncated-probit item response model for estimating psychophysical thresholds

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Human abilities in perceptual domains have conventionally been described with reference to a threshold, which may be defined as the maximum amount of stimulation which leads to baseline performance. Traditional psychometric links, such as the probit, logit, and  $t$ , are incompatible with a threshold as there are no true scores corresponding to baseline performance. We introduce a truncated probit link for modeling thresholds and develop a two-parameter IRT model based on this link. The model is Bayesian and analysis is performed with MCMC sampling. Through simulation, it is shown that the model provides for accurate measurement of performance with thresholds. The model is then applied to test the phenomenon of subliminal priming.

**Keywords:** Psychometrics, item response theory, psychophysics, thresholds, subliminal priming, hierarchical Bayesian models

## Detection by neuron populations.

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The mechanisms of detection processes pose a vexing problem in visual psychophysics: according to the simplest assumption a stimulus is detected if the maximum of the mean response of a neuronal channel (the one maximally activated by the stimulus pattern) reaches a threshold value – the *max-mean criterion*. Alternatively, the stimulus is detected if the maximum of the stochastically perturbed response reaches a critical value at an arbitrary time within a certain time interval (usually representing an experimental trial) – *temporal probability summation (TPS)*; a huge body of data in visual psychophysics is interpreted assuming either the max-mean or the TPS-criterion. An expression for detection by TPS, assuming Gaussian noise with an arbitrary autocorrelation function, is derived and applied to the prediction of step responses on the basis of independently determined impulse responses, and vice versa the prediction of impulse responses on the basis of the empirically determined step responses. The data turn out not to be compatible with the notion of detection by TPS but strongly support the max-mean criterion instead. The max-mean criterion will then be discussed with respect to the identification of the temporal course of activation processes in neuron populations in the context of object and contour detection.

## Mutual information in categorization models

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Equivalence between different categorization models (e.g. like the Similarity Choice Model or SCM, the General Recognition Theory or GRT, and the General Context Model or GCM) has been established before (Ashby & Maddox, 1993, *Journal of Mathematical Psychology*, 37, 372–400; Myung, 1994, *Journal of Mathematical Psychology*, 38, 335–365; Nosofsky, 1990, *Journal of Mathematical Psychology*, 34, 393–418). Here, the authors show that all these categorization models can be incorporated in the mathematical framework of a communication channel (Shannon, 1948, *The Bell Systems Technical Journal*, 27, 379–423).

The authors will elaborate on the idea of a communication channel metaphor and they will compare different paradigms in the categorization literature from an information theoretic approach. An important aspect of a communication channel is the average mutual information which can be thought of as the amount of information from the perceived images (represented by a vector) that is reflected in the response of the classifier. First, an exemplar representation and a prototype representation will be compared on the aspect of mutual information and secondly, a separable and an integral dimensional context for the input vectors will be compared too. In addition some suggestions will be made on how small changes to the existing models could lead to a better performance from an information theoretic point of view.

**Keywords:** information theory, categorization, communication channel

## Interindividual Differences in Mental Rotation of School-Aged Children: A Multilevel Growth Model Approach

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This study analyses 6- and 8-year-old children's response times in solving a stimulus comparison task. One hundred and eleven children ( $n = 54$  6-year-olds,  $n = 57$  8-year-olds) were asked to compare two figures differently oriented in a plane (from  $0^\circ$  to  $180^\circ$ ). In the experiment, we used two types of figure pairs (orientation and orientation free) and two types of stimuli (bears and cones).

In previous experiments, Perrucci (2003) and Perrucci, Agnoli and Albiero (in press) found differences in response times between 6- and 8-year-old children and between the two types of stimuli. However, since an ordinary least square regression model approach was used to analyse the data, interindividual differences in the relationship between response times and rotation were not considered.

Thus, the present study is based on a multilevel growth model approach (Pinheiro and Bates 2000; Bliese, 2006) to: (a) determine whether the response time randomly varies among individuals; (b) examine the form of the relationship between rotation and response time (i.e., linear or quadratic); (c) determine whether the relationship between rotation and response time is constant among individuals or whether it varies on an individual-by-individual basis; (d) assess the error structure of the model (i.e., test for both autocorrelation and heteroskedasticity); and (e) model inter-individual differences in the relation between rotation and response time as a function of participants' age and gender. In addition, the effects of types of figure pairs and type of stimuli were evaluated. Results and implications will be presented and discussed.

**Keywords:** Mental Rotation, Response Time Analysis, Interindividual differences, Multilevel Growth Model

## Luce's Axiom Testing Challenge and Possible Solutions

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Testing deterministic decision making axioms or relational structures against experimental choice data sends the researcher down a path fraught with conceptual, methodological and computational pitfalls. Some of these challenges are extremely counterintuitive, some involve unsolved mathematical problems, and some involve technical statistical hurdles that have only recently been overcome.

Luce (1995, 1997) highlighted the challenge in bridging the gap between algebraic (deterministic) relational structures (say, transitive relations, lexicographic semiorders, rank- and sign-dependent utility) and highly variable (probabilistic) empirical data (see also, e.g., Carbone & Hey, 2000; Harless & Camerer, 1994; Hey, 1995, 2005; Hey & Orme, 1994; Iverson & Falmagne, 1985; Loomes & Sugden, 1995 for important related discussions. We discuss a range of solutions to “probabilistic specification,” including aggregation based, distance based, and mixture (aka “random preference”) based specifications.

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## Item-response models for measuring human thresholds.

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Human abilities in perceptual domains have historically been conceptualized with reference to a threshold. Current approaches, however, define thresholds as corresponding to an arbitrary level of performance, say .75 or .707, rather than the maximum amount of stimulation which leads to baseline performance. My colleagues and I advocate a set of item-response models for measuring at-chance thresholds. Traditional psychometric links, such as the probit, logit, and t, are incompatible with a threshold as there are no true scores corresponding to baseline performance. We introduce a truncated probit link for modeling thresholds and develop a two-parameter IRT model based on this link. The model is Bayesian and analysis is performed with MCMC sampling. The model is applied to a digit-classification experiment in which digits are flashed briefly and then subsequently masked and individuals' threshold duration is estimated.

## Improved inductive item tree analysis

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A crucial problem in knowledge space theory is to build knowledge structures or surmise relations from data. Such a procedure is inductive item tree analysis, which was proposed by Schrepp [(1999). On the empirical construction of implications between bi-valued test items. *Mathematical Social Sciences*, 38, 361–375].

We discuss, correct and improve the algorithm. Theoretical arguments as well as simulation results confirm the quality of our improvements.

**Keywords:** Knowledge space theory, deriving knowledge structures, data analytic methods, inductive item tree analysis

## Development of model of an estimation of individual stability to stress

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Our study is devoted to a model construction. The model for an estimation of an individual level of stress resistance should be theoretically and empirically proved. We've allocated the general, integrated parameter of an individual stress resistance by means of the factorial analysis. We've offered the formula for calculation of an integrated parameter of stress resistance ISR. To get it, we've made the factorization of a basic sample's diagnostic system parameters. We used the principal components method, the method of structural equations (SEPATH). The Kaiser-Guttman criterion and the analysis of the schedule of factorial weights together led to the allocation of the unique factor (58,6 % of the explained dispersion), interpreted as the factor of "Stress resistance". Construction of an integrated parameter of an individual stress resistance on the basis of allocation of one factor during application of procedure of the exploratorial factorial analysis leaves the question about the multidimensionality of a studied phenomenon opened. The analysis of factorial structure of the parameters entering into diagnostic system for an estimation of individual stability to stress, consisted in comparison of four alternative models. During our analysis we've compared four theoretical IRS models: model I with one factor "Stress stability"; model II with four orthogonal factors of "Alarm", "Depression", "Anger" and "Exhaustion"; model III, including four correlating factors of "Alarm", "Depression", "Anger" and "Exhaustion"; model IV within four factors of the first order ("Alarm", "Depression", "Anger", "Exhaustion"), united in the factor of the second order (Stress stability). All models in addition contain two "methodical" factors - the factor of "Person" and the factor of "Situation" - general sources of a dispersion reflecting existence at personal and situational diagnostic parameters. Model II has appeared the worth. Models I, III (and  $\chi^2(61539; 2, df=5) = 42,9$ ; CFI = 0,995; SRMR = 0,015; RMSEA = 0,1) and IV have shown a similar level of conformity, however only in model III factorial loadings of all diagnostic parameters appear significant and are easily interpreted theoretically. We should note, that in model III allocated factors highly correlate each other, that has allowed us to improve model due to association of most strongly connected factors. Such association is represented conceptually to the most proved for factors "Alarm" and "Depression". Resultant model III has shown very high degree of the conformity to empirical data (and  $\chi^2(61539; 2, df=8) = 37,7$ ; CFI = 0,996; SRMR = 0,009; RMSEA = 0,07). Thus, multivariate estimations ISR has complex internal structure with the expressed interrelations between its components that reflects system character ISR as properties of the person. Individual stability to stress represents the system dynamic characteristic describing ability of the person to successful coping with inconvenient sit-

uations. Characteristic feature of high stability to stress is overcoming sharp and chronic stress without negative consequences for mental and physical health.

**Keywords:** stress resistance, model construction, factorial analysis

## A Formal Concept Analysis Approach to Statistical Hypothesis testing

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Hypothesis testing is the use of statistics to determine the probability that a given hypothesis concerning the equality of group-referred parameters such as sums, means, variances, proportions, probability is true. The canonical way to reach the right solution is to organize the whole process in four basic steps: hypothesis definition, identification of a test statistic that can be used to assess the truth of the null hypothesis, application of algebraic transformations over sampled parameters and conclusion. The central part of such a system of evaluation may be thought as an algebraic algorithm of operations' composition, whereas the first and the last one could not be conceived as algorithmically structured. Consequently, students may present a wide variety of solution's patterns related to their ability to solve the entire problem. Such ability should depend on the correct organization of the information derived from the three main parts.

In this work we have examined the solution of a "Hypothesis Testing for Differences between Paired Samples Means" problem subdivided into six parts: (i) hypothesis generation and formal expression, (ii) calculation of the algebraic sum of delta values between the pre-test and the post-test, (iii) calculation of the sum of squares of delta values, (iv) calculation of the t value, (v) identification of the correct critical t value for the acceptance-refusal of  $H_0$ , and (vi) the assumption of the correct decision from the comparison between the calculated t and the critical t value.

Different response patterns for the problem were obtained. The derived structure represents a partial order (Poset). The relation between response patterns and the single elements of the whole exercise can be well represented within the framework of the Formal Concept Analysis (Wille, 1982). From the analysis of the real response patterns of a sample of 114 students in a psychometrics course, we derived a Formal Context where the six parts of the "Hypothesis Testing for Differences between Paired Samples Means" problem were the formal attributes and the response patterns were the formal objects. In our sample only 25 of the  $2^6$  possible response patterns were encountered.

A Logistic Model has been applied to develop a measure of the adequacy of each solution

pattern actually observed.

**Keywords:** Formal Concept Analysis, IRT Models, Logistic Models, Knowledge Space Theory

## Probabilistic Models for Skill Maps

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The problems-to-skills relationship have been approached and modelled in both an algebraic and a probabilistic fashion from at least three different theoretical perspectives: Item response theory, Bayesian networks and knowledge space theory. In item response theory compensatory and noncompensatory conjunctive models for cognitive diagnosis have been developed. Examples of such models are the DINA, the NIDA and the linear logistic model. Knowledge structure theory provides the concept of a skill map, which is essentially a set-theoretic model of the relationship between problems and skills. Conjunctive skill maps delineate intersection-closed knowledge structures, and are formally equivalent to the Tatsuoka's  $Q$ -matrix which stands at the core of the DINA model. A typical limitation of this model is that it does not allow for multiple solution strategies. An algebraic model which elegantly overcomes this limitation is the skill multimap. A general result obtained by Doignon and Falmagne (1999) is that any knowledge structure is delineated by at least one skill multimap.

A class of noncompensatory probabilistic models for a skill multimap is presented and discussed, which can be seen as a generalization of the DINA model to multiple solution strategies. Within this class different models are considered, the simplest one being represented by the probabilistic skill map for independent skills. A logistic extension of the model is then introduced for modeling non independent skills, where dependence is specified through a suitable knowledge structure on the level of the skills.

A latent class extension of the model is also discussed, where the latent classes of subjects differ one another for the skill parameters or eventually for the different ways in which the skills are mapped to the problems. By this latent class extension multiple solution strategies for a problem can be postulated both within a single latent class (within single subjects) and between different latent classes (between different subjects).

Maximum likelihood estimation of the discussed models via the EM algorithm is considered.

**Keywords:** Skill maps, knowledge structures, probabilistic models

## Exploration of similarities and differences in loudness and brightness as informed by mathematical modeling

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In psychology, in contrast to in fields such as physics, a minority of the modeling efforts use classical mathematical modeling. Some seem even to view it with scorn, as did a reviewer that referred to one such model as “not even a psychophysical model” because it required its primitives to be defined in each testing modality. Yet, it is precisely this non-modality-specific approach that can make explicit fundamental and intriguing underlying relationships. A case in point is magnitude estimation/production, where Narens (1996) formulated two axioms that describe what he thought to underlie Stevens’ use of these methods. Many studies have subsequently evaluated these axioms in a variety of domains, including loudness, brightness, perceived size of circles, and more. In all studies to date, one axiom has been found to hold, the other to fail. These results suggest some commonality in how humans judge/process intensive dimensions. Luce (2002, 2004) formulated a theory of global psychophysics, which included and extended Narens (1996). This theory has been most extensively tested in loudness where it has found considerable support. Recently, I have worked to extend the evaluation to the perception of brightness and perceived contrast. The brightness results support Luce’s theory, and preliminary data for perceived contrast seem to as well. Given that the same model may describe behavior in both auditory and visual perception, an intriguing question emerges: what can this tell us about the similarities/differences between our eyes and ears? Clearly, the two sets of organs are very different in form and function; however, these mathematical modeling efforts reveal a perhaps surprising underlying commonality. This form of modeling allows such a commonality to be revealed as it formulates relationships between the primitives that must hold for the model to hold. Said another way, while data fitting may reveal functional forms that describe the data well, the mathematical modeling approach can lead to the same result as an induced property of underlying behavior, turning the functional form from result to prediction. This feature of mathematical modeling has not been much appreciated in psychology at large. With this theme in mind, I present a sampling of juxtaposed empirical results of the evaluation of several behavioral axioms in both audition and vision, with the aim of highlighting an underlying similarity in the way the eyes and ears combine stimuli.

**Keywords:** mathematical modeling, audition, vision, loudness, brightness, perceived contrast, axiomatic psychophysics, magnitude estimation, magnitude production

## Applying matroids to media, knowledge spaces, and other structures

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A matroid is a structure which captures the concept of independence in vector spaces without the usual linear algebra. It is investigated how this structure can be utilized to formalize dimension concepts in several applied situations. Moreover, in the recently developed theory of media matroids can be utilized. One obvious way is to describe the structure of a mediatic graph, i.e., the graph associated with a medium, as a graphic matroid using the edges of the graph as points and circuits as minimal dependent sets. However, there seems to be a deeper way which exploits the bipartiteness of the graph to cast it as a matroid. The possibilities of this a approach are investigated.

**Keywords:** Matroids, independence, dimension concepts, media theory, knowledge spaces

## Bootstrapping EEG data

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It has been forty years since I began speaking and publishing on the parallel vs. serial processing issue. This dichotomy might seem remarkable for its extreme simplicity combined with its tenacious resistance to resolution. The enigma was originally brought about through mathematical equivalence theorems, which indicated that in certain popular paradigms, and when response times (RT) increased with workload, parallel and serial systems were quantitatively identical, though vastly distinct in material construction. Over the intervening decades, a number of promising experimental designs emerged which were mathematically demonstrated to be capable of testing parallel vs. serial processing in deep and broad fashion. Most rely on RT distributions. Many of these have not been followed up but offer budding mathematical psychologists opportunities for new discoveries and experimentalists opportunities for rich explorations. The most popular of the robust strategies is based on what we refer to as "systems factorial technology". I will outline the state of the art of these approaches as viewed from my own laboratory and exhibit some very recent theoretical and, if time, experimental results where RTs unite with accuracy measures to create even stronger theory-driven methodologies.

## Evaluating fit measures for quasi orders

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Some requirements for evaluating the suitability of measures assessing the fit of quasi orders to binary data have been proposed. Those requirements not only concentrate on an unrealistic, ideal case, but also are so simulation-intensive that their actual verification is infeasible in general.

We present a new perspective on that issue, and clarify some methodological properties for such measures. Our elaborations are illustrated using the correlational agreement and diff coefficients.

**Keywords:** Fit measure, quasi order, evaluation, correlational agreement coefficient, diff coefficient

## Dealing with intractability in cognitive modeling: The good, the bad, the impossible, and the ugly

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Computational intractability is a problem that plagues many models of cognition. If such models are assumed to apply to inputs of real-world size and complexity, then they require more computational resources (e. g., speed or memory) than can be reasonably attributed to any finite mind/brain. Intractable cognitive models are explanatorily unsatisfactory as they seem to preclude an understanding of how the modeled cognitive ability can be computationally and physically realized. How can cognitive modelers deal with intractability of their models? In this talk, I review four different approaches that can be identified in the literature: model restriction, theory rejection, heuristics and approximation. I will argue that only the first is constructive; whereas the second is unjustified, the third is incoherent, and the last is ill-defined. I present a set of analytical techniques from parameterized complexity theory that can help cognitive modelers deal with intractability in a coherent and constructive fashion. The presented techniques will be illustrated using existing cognitive models.

**Keywords:** Cognitive modeling, computational tractability, heuristics, approximation, parameterized complexity

## Exact statistical tests of the race-model and related distribution inequalities

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Often, classes of models allow strong non-parametric predictions of how the response time distributions observed under different experimental conditions are related to each other. Examples are the race-model inequality (Miller, 1982), which specifies the maximum statistical facilitation for the faster of two parallel channels, its generalization to the fastest or the slowest of  $n$  channels (Colonius & Vorberg, 1993), and Sternberg's inequalities for serial self-terminating search (Sternberg, 1973; Vorberg, 1981). I present a one-sided non-parametric test of the null-hypothesis that a given inequality holds exactly, which permits testing any distribution inequality that can be expressed as a probability mixture with known mixing weights; the test corresponds to that proposed and analyzed first by Maris and Maris (2003). I show how the probability distribution of the test statistic under the null hypothesis can be computed exactly by enumeration of the corresponding Gnedenko paths, and demonstrate applications to simulated and to empirical data.

**Keywords:** race model inequality, distribution inequalities

## Mapping Response Tendencies with Ratcliff's (1978) Diffusion Model

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Ratcliff's (1978) diffusion model has proved useful as a tool in many areas of experimental psychology. This kind of analysis allows disentangling different processes underlying experimental effects. The diffusion model provides estimates for the speed of information accumulation, for the amount of information used to draw conclusions, and for judgmental biases. Speed of response execution is incorporated in an estimate for the duration of non-decisional processes. In the standard diffusion model it is implicitly assumed that both responses are executed with the same speed. We propose an extension of this model that allows mapping differences in the speed of response execution explicitly. Results from a simulation study demonstrate that parameter estimates from the standard model are biased if the speed of response execution differs between responses, while the extended model provides robust estimates.

**Keywords:** Diffusion Model, Response Tendency, fast-dm

## Bootstrapping EEG data

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Bootstrap is quite a young and in some fields of science yet unknown statistical, non-parametric resampling method. Bootstrapping has its strengths especially when datasets are small and statistical prerequisites are violated.

I present applications of Bootstrap to important problems from biological psychology, using EEG data. Bootstrapping is illustrated with classical statistical methods such as the one sample t-test, two sample t-test and permutation test. Bootstrapping is used for reliability analyses of such parameters as the median, mean and laterality coefficients. I also apply Bootstrapping for reanalyzing the marginally significant correlation and regression coefficients. All that is realized within the statistical computing environment S-Plus.

These elaborations make clear that if it comes to dealing with critical data, or if evaluating the statistical properties of specific data characteristics, Bootstrapping can be a very useful methodology.

**Keywords:** Bootstrap, EEG, S-Plus

## When times get rough, what would you do? Dealing with non-normality in reaction time experiments

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Strong evidence exists that observations obtained from reaction time (RT) experiments violate the normality assumption underlying parametric significance tests (e.g. Students'  $t$ -test). The present study investigates several strategies that deal with non-normally distributed RT observations.

In 60 % of the 385 experiments, published in 2000 in the *Journal of Experimental Psychology: Human Perception and Performance*, analyses of RT data were conducted. However, in 41 % of these studies neither outlier analyses nor any distributional considerations were mentioned. Rough trimming was the most prevalent procedure (47 %). Other approaches such as transformation or nonparametric tests were rather uncommon. Based on our review, commonly used criteria for trimming were chosen to compare the efficiency of this method with less common procedures.

Using Monte Carlo simulations the following methods were considered: two-sample  $t$ -test on (a) raw RTs, (b) trimmed samples with constant trimming using  $SD = 2, 2.5,$  and  $3,$  (c) trimmed samples choosing the amount of trimming adaptively (Léger & Romano, 1990), (d) log-transformed measures, and (e) transformed measures choosing an adequate transformation adaptively (Kirk, 1995). Additionally, (f) the Wilcoxon-Mann-Whitney-test (WMW) was used as a nonparametric competitor to the  $t$ -test. To simulate possible outcomes from RT experiments twelve ex-Gaussian distributions, listed in Miller (1988), were considered. Simulations were performed for sample sizes of  $n_1 (n_2) = 20 (30), 30 (30), 40 (30)$  and true differences in means were varied in four increasing steps. For each of the 144 conditions arising from the chosen simulation parameters, 50,000 iterations were realized.

Results reveal that all tests are robust for the twelve distributions. However, in sum the  $t$ -test on raw scores entails a power disadvantage. Data transformations are more powerful than the  $t$ -test on untransformed measures. The log-transformation is somewhat superior for highly skewed distributions (skewness  $\approx 2.09,$  kurtosis  $\approx 9.11$ ). In contrast, choosing a transformation adaptively is slightly more powerful than the log-transformation for less skewed distributions (skewness  $\approx 0.71,$  kurtosis  $\approx 4.54$ ). For these distributions an increasing amount of data trimming reduces the power of detecting true differences. For highly skewed distributions an increasing amount of trimming enhances the power of the  $t$ -test. Compared to constant trimming, choosing the amount adaptively shows a power disadvantage for highly asymmetric distributions. Results suggest that the WMW-test is most powerful for extremely skewed distributions with small differences in means. As true differences increase the log-transformation becomes similarly powerful.

## *Abstracts*

The results imply that commonly used methods may fail to detect true differences. Therefore, we suggest that when times get rough (i.e. highly skewed) and trimming is preferred, researchers can be quite courageous in choosing an appropriate amount.

**Keywords:** Non-normality, robustness, power, transformation, trimming, nonparametric tests

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