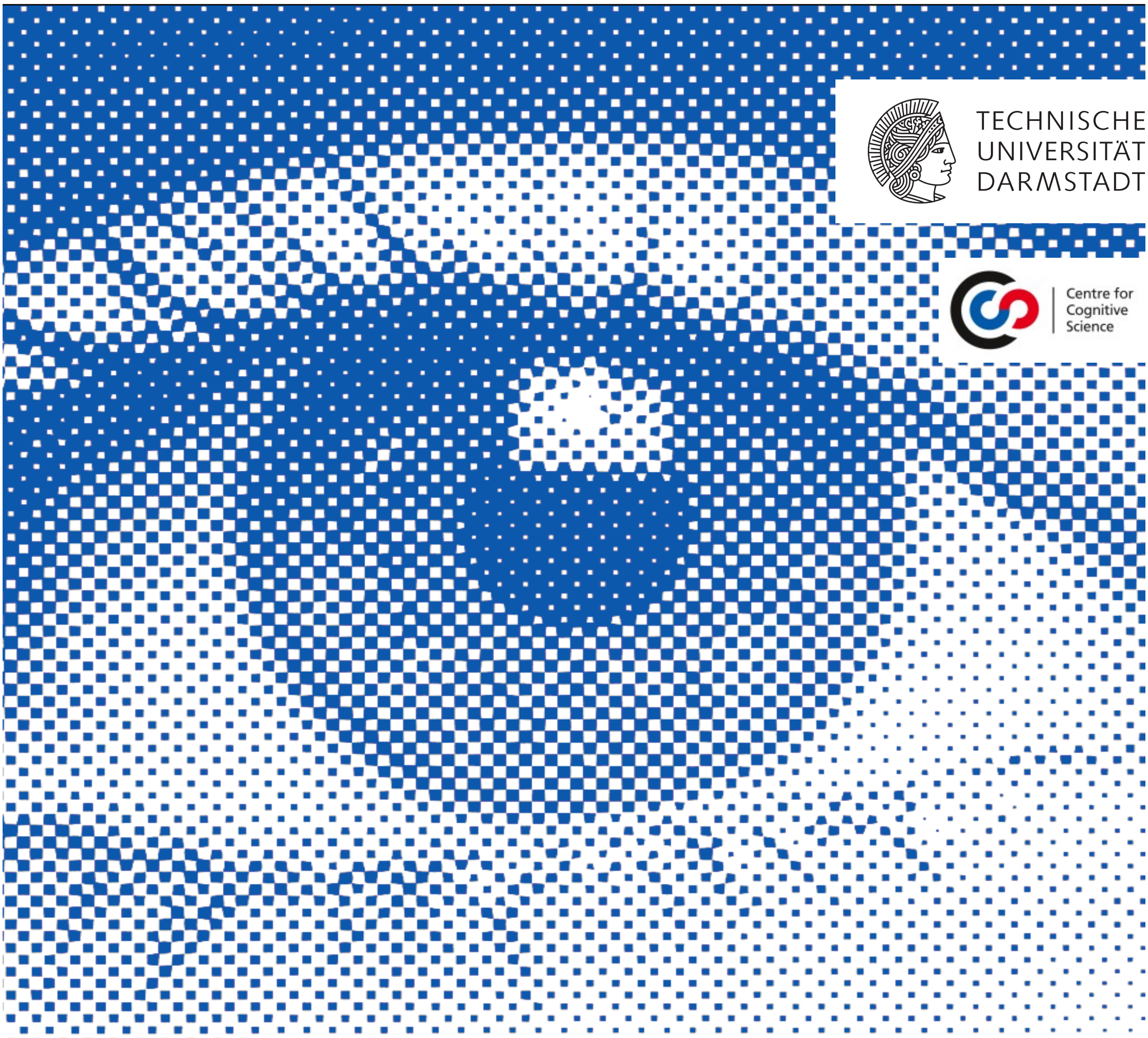
KOGWIS2018: Computational Approaches to Cognitive Science

14th Biannual Conference of the German Society for Cognitive Science, Sep 3-6, 2018

C. Rothkopf (chair), D. Balfanz, R. Galuske, F. Jäkel, K. Kersting, J. Macke, & B. Mohler



Gesellschaft für
Kognitionswissenschaft e.V.

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02 September 2018
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Welcome

Dear participant of KogWis 2018,

we would like to welcome you to the 14th meeting of the German Cognitive Science Society (*GK*, Gesellschaft für Kognitionswissenschaft, e.V.). Every two years the GK organizes this meeting that draws philosophers, linguists, neuroscientists, psycholgists, and computer scientists not only from Germany but also from the rest of Europe and beyond. We, the organizers and members of the new Centre for Cognitive Science at Technische Universität Darmstadt, are very proud to host this conference here in Darmstadt for the first time.

Darmstadt has a long history going back to the 11th century and holds the official title *City of Science* (German: Wissenschaftsstadt) because it is a major centre of scientific institutions, universities, and high-technology companies. The European Space Operations Centre (ESOC) is located in Darmstadt, as well as the GSI Centre for Heavy Ion Research where several chemical elements were discovered. The Technische Universität Darmstadt is one of the leading technical universities in Germany with strong departments in engineering, physics, and computer science. Within close proximity lie Frankfurt, with the Goethe University and three Max Planck Institutes directly related to neuroscience, Mainz with the Johannes Gutenberg University, and also the Justus Liebig University of Giessen is not far. This combined expertise in neuroscience, psychology, and computer science is an ideal environment for the new Centre for Cognitive Science at TU Darmstadt. The Centre was was founded in 2016, is still expanding, and next year we hope to start new undergraduate and graduate programs in cognitive science. The research focus at the Centre for Cognitive Science in Darmstadt will be on Computational Approaches to Cognitive Science and, hence, we have decided to also make this the focus topic of this year's KogWis.

We are very happy to have been able to attract a great line-up of keynote speakers. The first keynote on Monday will be by Tessa Dekker (University College London) who will present recent work on how sophisticated abilities in perception and action are learned throughout development. Later that day, Frances Egan (Rutgers University) will investigate the use of the concept of *representation* in computational cognitive models. On Tuesday, Christopher Summerfield (University of Oxford) will present recent work on understanding why humans are still superior to any artificial intelligence and how this understanding could lead to stronger AI systems. In the afternoon, Iris van Rooij (Radboud University Nijmegen) will demonstrate the relevance of complexity theory in understanding fundamental problems in computational models of cognition. Wednesday will be opened by a talk by Maté Lengyel (University of Cambridge & CEU) who will give an overview of his computational work relating statistical properties of the environment to properties of internal cognitive models explaining behavioral and neural phenomena. The last talk on Wednesday afternoon will be given by Noah Goodman (Stanford University) applying methods from probabilistic machine learning to explain how language works.

The abstracts for posters and presentations have all been thoroughly reviewed by our program committee (see next page), for which we are very grateful. Despite its traditionally rather small size, we received over 80 submissions to KogWis 2018 out of which we accepted 20 abstracts as oral presentation and most of the others as poster presentations. All abstracts were carefully revised and are included in these proceedings. The overall program of KogWis 2018 also comprises a number of invited symposia addressing specific topics in cognitive science, tutorials, a doctoral symposium, as well as the GK best paper talk and the presidential lecture. The scientific program is complemented by the social dinner and the GK Society Meeting.

We would like to thank the many people at TU Darmstadt, especially Inge Galinski, Ute Leischer, Linda Wiesinger, and all the student volunteers who have helped to make this conference happen. We would also like to thank all the organizers of previous KogWis meetings and the governing board of the society who shared all their insights about planning this conference. Last but not least, we would also like to thank the Deutsche Forschungsgemeinschaft (DFG) that has, again, helped with funding.

We very much hope that you will enjoy KogWis 2018, that you will engage in inspiring chats with colleagues, and that you will have a wonderful time in Darmstadt.

September 2018
Darmstadt

Constantin Rothkopf (chair)
Dirk Balfanz
Ralf Galuske
Frank Jäkel
Kristian Kersting
Jakob Macke
Betty Mohler

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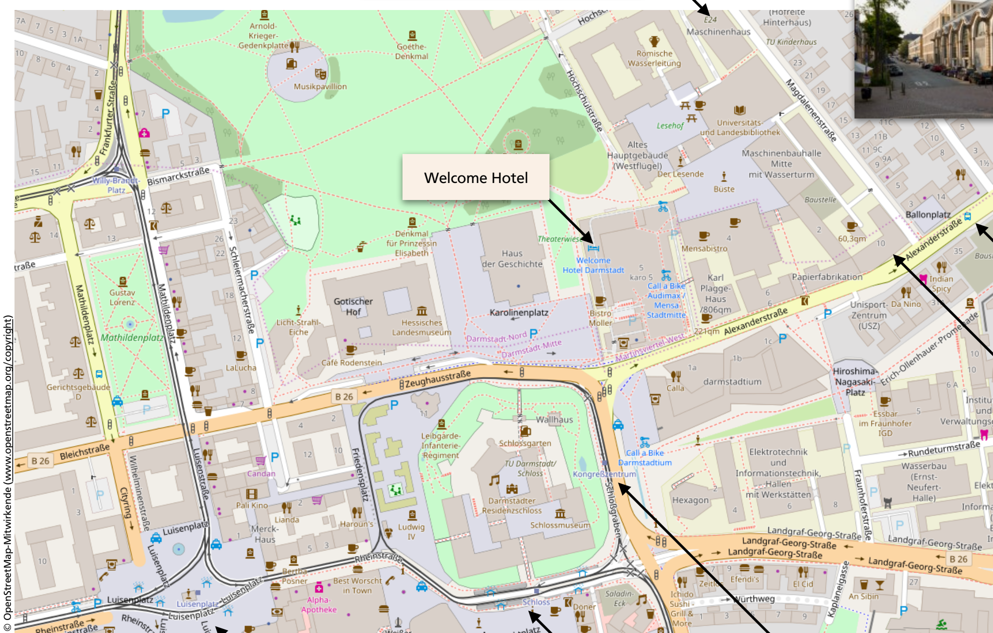
Diedrich Wolter	Universität Bamberg
Carlos Zednik	Universität Magdeburg

KOGWIS 2018 - Schedule (updated 15.08.2018)

h	Sun. 2nd Sep.	Mon. 3rd Sep.	Tue. 4th Sep.	Wed. 5th Sep.	Thu. 6th Sep.	h
08:00		Registration	Registration	Registration	Registration	08:00-09:00
08:45-09:00		Welcome Address				
09:00-10:00		Keynote: Tessa Dekker	Keynote: Christopher Summerfield	Keynote: Máté Lengyel	Doctoral Symposium	09:00-10:00
10:00-10:30		*Coffee Break*	*Coffee Break*	*Coffee Break*		10:00-10:30
10:30-12:00		Main track: Philosophy of Cognition / Symposium: Cognitive Technical Systems - Towards Fluid Assistants?	Main track: Judgment and Decision Making / Symposium: Multinodal Processing in the Visual System	Main track: Cognitive Neuroscience / Tutorial: Bayesian Modeling		10:30-12:00
12:00-14:00		*Lunch Break*	*Lunch Break*	*Lunch Break*	*Lunch Break*	12:00-14:00
14:00-15:00		Keynote: Frances Egan	Keynote: Iris van Rooij	Keynote: Noah Goodman		14:00-15:00
15:00-15:30		*Coffee Break*	*Coffee Break*	*Coffee Break*		15:00-15:30
15:30-17:30		Poster Session	Main track: Thinking and Reasoning / Tutorial: Deep Learning	Main track: Language and Communication / Symposium: Cognitive Modeling in Comp. Science and Psychology		15:30-17:00
17:30-19:00	Registration	GK Society Meeting	Paper Award + Presidential Address	Poster Session		17:00-19:00
19:00			Social Event			19:00

CCS / 15.08.2018

Conference Venue
TU Darmstadt, S1 | 05, Maschinenhaus
Magdalenenstr. 12, 64289 Darmstadt



Welcome Hotel

Bus Stop
TU/Alexanderstr.
Lines F, F/U, H, KU

Early registration
Sunday 17:30-19:00
Inst. of Psych.
Alexanderstr. 10
64289 Darmstadt

Luisenplatz
(City Centre)
Tram Lines 2, 3, 4, 5, 6, 7, 8, 9,
Bus Lines K, L, F, F/U, H, AIR

Schloss
(Palace)
Tram Lines 2, 3, 9
Bus Lines K, L, F, F/U, H

Kongresszentrum/Darmstadtium
(Express Bus from/to Frankfurt Airport)
AIR

Keynotes

Tessa Dekker (University College London)

Monday, Sep 3, 9:00-10:00

How do we develop an optimised sensorimotor system?

Humans are born with exceptionally poor visual and motor skills but by the time they reach adulthood, most vision and action is highly proficient and near-automatic. My lab investigates the processes that support this development. I will present data showing that adults' are highly adept at accounting for the noise in their sensory estimates and the imprecisions of their movements. This allows them to form judgments and choose actions with a high chance of success – even in highly complex environments. Our recent research shows that this is not a trivial ability to acquire – using a combination of model-driven neuroimaging and behavioural methods, we demonstrate that children as old as 10-11 years do not correctly account for the noise in their system during vision and visually-guided action, and are placed at unnecessary risk of failing at basic tasks as result. I will present some examples of tasks that are substantially affected by this development, and present modelling work aimed at disentangling which processes drive this shift from suboptimal sensorimotor processing in childhood to the highly optimised performance in adults.

Frances Egan (Rutgers University)

Monday, Sep 3, 14:00-15:00

The role of representation in computational models

Much of cognitive neuroscience construes cognitive capacities as representational capacities, or as involving representation in some way. Computational theories of vision, for example, typically posit structures that represent edges in the world. Neurons are often said to represent elements of their receptive fields. Despite the widespread use of representational talk in computational theorizing there is surprisingly little consensus about how such claims are to be understood. Some argue that representational talk is to be taken literally; others claim that it is merely a useful fiction. In this talk I sketch an alternative account of the nature and function of representation in computational cognitive models that rejects both of these views.

Christopher Summerfield (University of Oxford)

Tuesday, Sep 4, 9:00-10:00

Ingredients of intelligence in minds and machines

There is considerable current excitement about advances in machine learning. However, artificial systems fail on a number of problems that humans master. For example, humans efficiently generate temporally extended behaviours (planning), can generalise abstract information (far transfer) and can perform multiple tasks in quick succession (multitasking). I will describe recent experiments that examine the neural and computational mechanisms underpinning these abilities, and discuss how the resultant insights might be used to build stronger AI.

Iris van Rooij (Radboud University Nijmegen)

Tuesday, Sep 4, 14:00-15:00

Why cognitive scientists should care about computational complexity

Computational complexity theory studies the computational resources (e.g., time, space, randomness, etc.) required for solving computational problems. Its analytical tools aren't yet commonly taught in cognitive science and many still go about their business without much concern for the computational resources presupposed by their theories and models. Yet, there are good reasons for cognitive scientists to care more about computational complexity. In this talk I will explain how computational complexity theory provides useful analytical tools to guide and constrain computational-level theorizing and how it can help bring rigor and clarity to long-standing debates that center on the notion of computational intractability—e.g., rationality vs. irrationality, modularity vs. domain-generality, cognitivism vs. enactivism.

Christoph Hölscher (ETH Zürich & President of GK)

Tuesday, Sep 4, 17:00-18:00

Presidential Address and GK Best Paper Award

Máté Lengyel (University of Cambridge & Central European University)

Wednesday, Sep 5, 9:00-10:00

A Bayesian approach to internal models

Our percepts rely on an internal model of the environment, relating physical processes of the world to inputs received by our senses, and thus their veracity critically hinges upon how well this internal model is adapted to the statistical properties of the environment. We use a combination of Bayesian inference-based theory and novel data analysis techniques applied to a range of human behavioural experiments, as well as electrophysiological recordings from V1, to reveal the principles by which complex internal models (1) are represented in neural activities, (2) are adapted to the environment, (3) can be shown to be task-independent, and (4) generalise across very different response modalities.

Noah Goodman (Stanford University)

Wednesday, Sep 5, 14:00-15:00

How language works

Cognitive Technical Systems – Towards Fluid Assistants?

Monday, Sep 3, 10:30-12:00

Stefan Kopp & Ute Schmid

Modern Artificial Intelligence and Cognitive Systems are on the verge of penetrating the everyday life of human users and to free them of many tasks that are cumbersome, dangerous or exceed their abilities and resources. We are witnessing such systems being developed for, e.g., entertainment, healthcare, educational, or workplace settings, and they are being deployed by commercial players at an increasing pace. The goal is to assist users in their tasks and the systems attain a variety of roles and interaction paradigms in doing so, from responding to user instructions, to providing recommendations, engaging in negotiations, to carrying tasks or subtasks autonomously. In result, we expect to see a variety of integrated ("hybrid") settings in which humans and technical systems come to collaborate in different ways in order to solve even time- or safety-critical tasks. However, and in spite of the apparent technology push, a number of crucial questions are far from being sufficiently understood or solved: How can cognitive systems recognize and represent the state of users adequately? How can assistants support their users in a non-distracting, unobtrusive way? How do systems need to adapt to the specific requirements of the user and the demands of a given situation and task? How can machine learning and computational cognitive science help to obtain deeper user models and policies for suitable assistance? How to evaluate and validate the acceptance and efficacy of such systems? How to ensure safety and reliability of human-machine systems in safety- critical environments? How can users understand and be kept aware of the abilities and limitations of an assistance system? Can systems themselves assess their current limitations and effects (supportive or harmful) and use this to choose a suitable assistive behavior? This symposium aims to bring together researchers from different disciplines, from Cognitive Science and Artificial Intelligence, Engineering and Control, to Psychology and Human Factors, to discuss the state-of-the-art in technical approaches to developing and applying cognitive systems for user assistance. It is thus closely related to KogWis 2018's special focus on computational approaches to Cognitive Science. A special focus will be put on the notion of "fluid assistance" – the ability of technical cognitive systems to uphold a deep understanding of the dynamically changing situation, task demands and the user's internal states (cognitive, affective, or physiological) and to adapt flexibly and continuously the way in which to support the user. This vision, representing a next stage of user-adaptive assistive systems, combines and resolves the boundary between different roles, interaction modes and assistive effects a cognitive system can realize.

List of speakers:

- Ute Schmid (Cognitive Systems Group, University of Bamberg): Explaining Classifier Decisions in an Interactive Learning Environment
- Meike Jipp (Human Factors and Testing, Institute of Transportation Systems, DLR): User-state recognition as challenge for empathic assistants and automization
- Andreas Wendemuth (Cognitive Systems, Institute for Information Technology and Communication, University of Magdeburg): Intelligent driver assistants
- Dirk Söffker (Dynamics and Control, Fac. Of Engineering, University of Duisburg-Essen): Intention and option: Modelling and Recognition of human driver behavior
- Stefan Kopp (Social Cognitive Systems, Center of Excellence Cognitive Interaction Technology, Bielefeld University): Cognitive Systems for deep and fluid assistance and collaboration

Multinodal Processing in the Visual System

Tuesday, Sep 4, 10:30-12:00

Ralf Galuske

The aim of this symposium is to elucidate the functional and dynamical interactions between different centers in the mammalian visual system and to identify their relevance for information processing in the central nervous system.

- Julien Vezoli (Ernst Strüngmann-Institute, Frankfurt/M, Germany): The Relation between Anatomical Connection Strength and Inter-areal Functional Connectivity through Rhythmic Synchronization

- Ralf Galuske (Centre for Cognitive Science, TU Darmstadt, Darmstadt, Germany): Functional Topography of Cortical Feedback Connections in the Visual System
- Miriam Müller (Ernst Strüngmann-Institute, Frankfurt/M, Germany): Revising the Interhemispheric Imbalance Model of Neglect
- Ricardo Kienitz (Dept. of Neurology, Frankfurt University Medical School, Frankfurt/M, Germany): Theta Rhythmic Spiking and Attentional Sampling Arising from Cortical Receptive Field Interactions
- Michael Wibral (Dept. of Psychiatry, Frankfurt University Medical School, Frankfurt/M, Germany): Neural Information Dynamics from Cells to Systems

Cognitive modeling in computer science and psychology: Bridging the gap

Wednesday, Sep 5, 15:30-17:00

Rebecca Albrecht & Mikhail Spektor

Formal modeling approaches to human cognition is the cornerstone method of cognitive science. Its various sub-disciplines, including computer science, neuroscience, and psychology, rely on the computational perspective as a window to cognition. However, the methods and models that are being used as well as the goals of using cognitive modeling differ between them. For example, cognitive models in computer science rely on the assumption that cognitive processes are the result of general learning mechanisms that are able to find systematic patterns in unstructured data. These machine-learning methods span from low-level connectionist mechanisms to high-level logical representations. The former aim to describe basic cognitive and biological functions such as vision and motor action, whereas the latter describe higher level cognitive and executive functions, like reasoning and planning. In psychology, cognitive models are used in conjunction with behavioral data and fall on the continuum between the poles measurement models and process models. Process models explicitly formalize the assumed underlying cognitive processes such as attention, perception, or memory. These models are then evaluated relative to alternative models, rigorously selecting the processes that are essential and ruling out those that are not. In contrast, the mechanisms underlying measurement models are inherently agnostic with respect to the psychological processes they reflect. The associated model parameters gain psychological content through behavioral differences across experimental conditions. The question of how the different approaches to cognitive modeling may inform and benefit each other has been subject of discussion in the literature. The arguably most popular approach is the cognitive architecture ACT-R (Anderson, 2004, Psychol. Rev). ACT-R combines high-level rule representations with process assumptions about memory retrieval. However, ACT-R models suffer from various difficulties, including interpretation and falsifiability. The aim of the proposed symposium is to discuss different cognitive-modeling approaches from the various sub-disciplines of cognitive science, identify the overlaps between them, and critically reflect existing hybrid models. To do so, it comprises a total of five speakers from computer science and psychology, each representing a different aspect of the cognitive-modeling spectrum. The cornerstones of modeling techniques from computer science will be presented by Fabian Schrodt, introducing a neural-network model of social action understanding based on embodied simulation, and Ute Schmid, presenting a rule-learning framework with inductive programming as its basis. From psychology, Gidon Frischkorn will show the merits and limitations of using cognitive models as measurement tools and Mikhail Spektor will show an example of how process models are developed and evaluated. The symposium will conclude with a brief introduction about the ACT-R and will transition into an overarching discussion.

Speakers and talk titles:

- Mikhail S. Spektor (University of Freiburg): Implementing value-based attentional capture in a computational process model of cognition
- Gidon Frischkorn (University of Heidelberg): Using cognitive models as measurement tools: The appropriate representation of a person's cognitive processes
- Fabian Schrodt (University of Tübingen): A neurocomputational model of action understanding
- Ute Schmid (University of Bamberg): Inductive programming: A generic approach to rule learning on the knowledge level
- Rebecca Albrecht (University of Basel): Is ACT-R enough? The merits and flaws of hybrid cognitive architectures

Tutorials

Neural and Probabilistic Deep Learning

Tuesday, Sep 4, 15:30-17:00

Kristian Kersting

Our minds make inferences that appear to go far beyond standard machineclearning. Whereas people can learn flexible representations and use them for a wider range of learning tasks, traditional machine learning algorithms have been mainly employed in a rigid way, constructing a single function from a table of training examples. In this tutorial, I shall review deep learning approaches, a more flexible function approximation. Specifically, I will touch upon function approximators like convolutional neural networks that are robust and allow for real-time inference. However, they requiring fixed inputs and outputs and do not provide probabilities. Therefore I will also touch up upon Sum-product networks (SPNs). They are deep models that are suitable for both function approximation and probability estimation. Overall, I will review generative and discriminative deep learning approaches, both in a neural and (explicit) probabilistic fashion.

Bayesian Modeling

Wednesday, Sep 5, 10:30-12:00

Constantin Rothkopf & Frank Jäkel

The first part of the course is a basic introduction to probability theory from a Bayesian perspective. We will also discuss how Bayesian inference differs from frequentist inference. In the second part of the course we will discuss why Bayesian Decision Theory provides a good starting point for probabilistic models of perception and cognition. The focus here will be on Rational Analysis and Ideal Observer models that provide an analysis of the task, the environment, the background assumptions and the limitations of the cognitive system under study. We will go through several examples from signal detection to categorization to illustrate the approach.

Main Track

Philosophy of Cognition

Monday, Sep 3, 10:30-12:00

- Albert Newen*. Cognitive penetrability of perceptual experience: how the activation of concepts (or background information) can modify our perceptual experience
- Wanja Wiese*. Computing the valence of pleasure and pain
- Leda Berio*. Mental state terms, conceptual acquisition and mismatching representations
- Anna Strasser*. Joint actions and artificial agents

Judgment and Decision Making

Tuesday, Sep 4, 10:30-12:00

- Pablo León-Villagrá*, Irina Preda and Christopher G. Lucas. Data availability and function extrapolation
- Rebecca Albrecht*, Janina A. Hoffmann, Timothy J. Pleskac, Jörg Rieskamp and Bettina von Helversen. Explaining quantitative judgments with a mixture model combining exemplar retrieval and cue-abstraction
- Ulrike Senftleben*, Martin Schoemann and Stefan Scherbaum. Modulation of choice perseveration in delay discounting decision making
- Sayan Gul, Paul Krueger, Frederick Callaway, Tom Griffiths and Falk Lieder*. Discovering rational heuristics for risky choice

Thinking and Reasoning

Tuesday, Sep 4, 15:30-17:00

- Kai Hamburger* and Markus Knauff. Visual imagery in human reasoning
- Lukas Elflein* and Marco Ragni. Diversity in reasoning: A challenge for cognitive modeling
- Parthena Kounatidou, Mathis Richter*, Jonas Lins and Gregor Schöner. A neural dynamic architecture autonomously builds mental models and makes inferences on them
- Stefan Depeweg, Constantin Rothkopf and Frank Jäkel*. A visual language for solving Bongard problems

Cognitive Neuroscience

Wednesday, Sep 5, 10:30-12:00

- Sen Cheng*, Mehdi Bayati and Amir Hossein Azizi. Intrinsic sequences in the hippocampus for spatial navigation and episodic memory
- Daniel Schad* et al. A selective neuronal representation of incentive salience in Pavlovian conditioning
- Zahra Moradi, Keyvan Yahya* and Eckart Altenmüller. The effects of music-based interventions on Parkinson disease
- Heiko Schütt*, Lars O. M. Rothkegel, Hans A. Trukenbrod, Ralf Engbert and Felix A. Wichmann. Predicting the fixation density over time

Language and Communication

Wednesday, Sep 5, 15:30-17:00

- Mark Blokpoel* et al. Ambiguity helps higher-order pragmatic reasoners communicate
- Jan Pöppel* and Stefan Kopp. Towards satisficing mental models for behavior understanding
- Simon Kirsch* and Lars Konieczny. The psychological reality of verb-argument constructions: A visual world eye-tracking study
- Milena Rabovsky* and James L. McClelland. How event probability impacts sentence comprehension: Modeling N400 amplitudes in reversal anomalies

Abstracts (Alphabetical by First Author)

Towards a Computational Model of Child Gesture-Speech Production

Olga Abramov, Stefan Kopp, Anne Németh, Friederike Kern, Ulrich Mertens, and Katharina Rohlfing*

Previous work by [1] studied gesture-speech interaction in adults. [1] focussed on temporal and semantic coordination of gesture and speech and found that while adult speech is mostly coordinated (or redundant) with gestures, semantic coordination increases the temporal synchrony. These observations do not necessarily hold for children (in particular with respect to *iconic* gestures, see [2]), where the speech and gesture systems are still under development. We studied the semantic and temporal coordination of speech and gesture in 4-year old children using a corpus of 40 children producing action descriptions in task oriented dialogues.

In particular, we examined what kinds of information are transmitted verbally vs. non-verbally and how they are related. To account for this, we extended the semantic features (SFs) developed in [3] for object descriptions in order to include the semantics of actions. We coded the SFs on the children's speech and gestures separately using video data.

In our presentation, we will focus on the quantitative distribution of SFs across gesture and speech. Our results indicate that speech and gestures of 4-year olds are less integrated than those of the adults, although there is a large variability among the children. We will discuss the results with respect to the cognitive processes (e.g., visual memory, language) underlying children's abilities at this stage of development. Our work paves the way for the cognitive architecture of speech-gesture interaction in preschoolers which to our knowledge is missing so far.

[1] Bergmann K, Aksu V, Kopp S. The Relation of Speech and Gestures: Temporal Synchrony Follows Semantic Synchrony; 2011.

[2] Capirci O. Gesture and speech. Dimensions of gesture. 2008;.

[3] Bergmann K, Kopp S. Verbal or Visual? How Information is Distributed across Speech and Gesture in Spatial Dialog. In: Schlangen D, Fernandez R, editors. brandial 06. Proceedings of the 10th Workshop on the Semantics and Pragmatics of Dialogue (SemDial-10). Potsdam: Universitätsverlag; 2006. p. 90–97.

*corresponding author (email: oabramov@techfak.uni-bielefeld.de)

Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Explaining Quantitative Judgments with a Mixture Model Combining Exemplar Retrieval and Cue-abstraction

Rebecca Albrecht, Janina A. Hoffmann, Timothy J. Pleskac, Jörg Rieskamp and Bettina von Helversen*

From a judge passing sentence on a convict to a financial analyst evaluating the risk of a stock, evaluating situations and judging the value of objects is a widespread and important cognitive task.

Research on quantitative judgments from multiple cues suggests that judgments are simultaneously influenced by previously abstracted knowledge about cue-criterion relations (cue abstraction) and memories of past instances (exemplar retrieval) [e.g. 2]. Yet extant judgment theories leave two questions unanswered: (a) How are exemplar retrieval and abstracted cue knowledge combined to form a judgment? (b) Are all exemplars retrieved from memory to form a single judgment as exemplar theory suggests (integrative retrieval) [3] or is the judgment based on one exemplar, as e.g. assumed in the ACT-R cognitive architecture (competitive retrieval) [1]. To address these questions we propose a new cognitive model. In a first step, a single exemplar is recalled from memory. In a second step, the recalled exemplar's criterion is adjusted based on abstracted cue knowledge.

We tested the model's qualitative predictions in two experiments. In both experiments, participants first learned a small number of training items. In a subsequent test phase old and novel items had to be judged repeatedly without feedback. Experiment 1 assessed whether the criterion value of the assumedly retrieved exemplar is adjusted based on cue knowledge. A mixed model analysis confirmed that participants' responses correspond to an adjustment predicted by cue-abstraction models. Experiment 2 contrasted competitive retrieval against integrative retrieval by manipulating the spread of similar items over the response scale. Integrative retrieval predicts an outcome as a linear combination of memory items' judgment values. Thus, the predicted response distribution is uni-modal and across-item variability is constant. Competitive retrieval predicts across-item variability as a function of items' similarity structure in memory: the higher the distance between similar memory items on a response scale the higher the variability. In addition, multimodal response patterns are predicted within participants. The predicted multinomial response distributions were found across and more importantly within-participants. A mixed model analysis confirmed the qualitative result. A quantitative model comparison contrasted the model with six alternative models. The results show that our model explains responses best (mean BIC, number of best-fitted subjects).

Our results suggest that the presented model is a viable explanation for quantitative judgments and show the importance of considering judgment variability in addition to average responses in judgment research.

[1] Anderson, J. R. et al. (2004). An integrated theory of the mind. *Psychological review*, *111*(4), 1036-1060.

[2] Hahn, U. et al. (2010). Exemplar similarity and rule application. *Cognition*, *114*(1), 1-18.

[3] Nosofsky, R. M. (2011). The generalized context model: An exemplar model of classification. *Formal approaches in categorization*, 18-39.

*corresponding author (email: rebecca.albrecht@unibas.ch)

Judgment and Decision Making, Tuesday, Sep 4, 10:30-12:00

The cognitive utility of flawed metaphors in mathematical problem-solving

*Benjamin Angerer**

It has been proposed that metaphors are not solely a phenomenon of non-literal linguistic expression, but that they play a much broader role for our conceptual system, i.e. in reasoning, learning, and thinking [3,4]. Instead of talking about something in terms of another, when using a metaphor we are actually *understanding* it in those terms. Such *conceptual metaphors* are described as unidirectional mappings between subsets of two knowledge domains, such that the inferential structure of the (familiar) source is preserved in the (less familiar) target.

Noting that metaphors thus provide a potential mechanism to derive abstract knowledge from concrete experiences (cf. [2]), Lakoff and Núñez proposed that mathematical knowledge could be derived from a series of grounding and linking metaphors. However, their investigation has mostly concentrated on metaphors well-established in mathematical discourse [6].

The presented project aims instead to provide insight into metaphors as they *spontaneously occur* to individuals trying to understand and solve new problems. Since such situations are characterised by little prior knowledge, metaphors produced spontaneously often are idiosyncratic and flawed to some extent (cf. [5]). In spite of this, they are not simply discarded, but can still be of use in problem solving, e.g. by highlighting unknown aspects of the target domain, or by heuristically guiding the construction of new, more apt metaphors.

Here, we present an overview of (a) the different kinds of flaws metaphors can exhibit, (b) rectification strategies which can be adopted, and (c) their cognitive utility. This theoretical discussion is based on a series of protocol studies conducted using a complex spatial transformation and problem solving task in the domain of iterated mental paper folding [1].

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Mental State Terms, Conceptual Acquisition and mismatching representations

*Leda Berio**

The aim of my talk is to present a model for the acquisition of mental states concepts that attributes a fundamental role to determined syntactic structures in allowing the formation of representations of mental states used in explicit mindreading tasks.

The false belief task is famously hard to solve for children under 4 years old. The presented model, compatible with double-mechanisms approaches to belief reasoning [1], builds up on de Villiers approach [2] in arguing that acquisition of complement structures is a fundamental step in the acquisition of the representational means to solve this kind of belief reasoning problem.

It will be argued that acquisition of complement structures provides a mechanism that allows children to:

1. Form a *relational* representation of a mental state that involves an *holder.*
2. *Compare* the content of the mental state with what is perceived by the child herself.

This kind of format allows the child to acquire a fundamental feature of mental states, i.e. the fact they can potentially be mismatching reality, and hence be false. This is achieved because the representation acquires a feature, that will be spelled out in terms of attribute-values structure, that can be considered as "(mis)matching with what is perceived/known". This kind of representation of falsity is particularly complex and its lack gives rise to problems with false representations that go beyond false belief tasks [3].

Explicit false belief tasks can be solved once the proper mental vocabulary is acquired, that allows for more sophisticated, relational representations of other people's mental states and for the direct comparison between representations. This is in line with the literature linking language acquisition and false belief task solving skills in a correlational and functional sense [4, 5].

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Philosophy of Cognition, Monday, Sep 3, 10:30-12:00

Ambiguity helps higher-order pragmatic reasoners communicate

Mark Blokpoel, Mark Dingemanse, George Kachergis, Sara Bögels, Linda Drijvers, Lotte Eijk, Mirjam Ernestus, Naomi de Haas, Judith Holler, Stephen Levinson, Rui Lui, Branka Milivojevic, David Neville, Asli Ozyurek, Marlou Rasenberg, Herbert Schriefers, James Trujillo, Tobias Winner, Ivan Toni, Iris van Rooij*

Imagine you want to tell your friend an anecdote about a class mate. Neither of you know the person's name. How can you convey who you are referring to? You could refer to features of the person (e.g., 'the one with red hair' or 'the tall one') or use more metaphorical terms (i.e., 'the teacher's favorite' or 'the gamer'). Of all the things you could say, in principle, how do you decide what to say? This communication problem cuts at the core of some of the key challenges in explaining the computational cognitive infrastructure of human communication [1].

We report some first results from a consortium-based approach aimed at tackling these problems empirically and theoretically. We use cognitive agent-based simulations to investigate which cognitive capacities are necessary and sufficient to achieve mutual understanding. We manipulate signal ambiguity (e.g., 'the tall one' may refer to one or many class mates), knowledge asymmetry (e.g., your friend may not know that Mary is 'a gamer'), and pragmatic inference to study the effects on success in a communication game. The game is informed by a director-matcher task used to study mutual understanding [2].

We show that agents can communicate successfully under various conditions. In the limiting case where both agents share the exact same 1-to-1 signal-referent mappings (no ambiguity and no asymmetry), communication is obviously successful. However, this success is vulnerable to increased ambiguity or asymmetry. Some measure of success may be recovered by endowing agents with pragmatic inference abilities [3]. Crucially, we find that higher-order asymmetrical agents can understand each other better than zero-order agents with exactly matched vocabularies, but only when vocabularies are ambiguous. This counterintuitive role of ambiguity under asymmetry shows the importance of exploring the boundary conditions under which referential communication between two interacting agents can be successful.

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Language and Communication, Wednesday, Sep 5, 15:30-17:00

How spectators watch dancers moving together: effects of experience, intention and preference on visual attention

Bettina Bläsing, Elizabeth Waterhouse*

Little is known so far about how spectators watch dancers moving together, and how this relates to their own dance-related experience. In this project, we used eye-tracking and questionnaires to investigate how spectators watch contemporary dance choreography presented as video material, and how they monitor synchronicity and interactions between dancers. We were particularly interested to what extent the intention to mark the dancers' togetherness in movement and the personal preference and evaluation of the dancers and the dance piece would influence spectators' visual attention, and which criteria for monitoring synchronicity they would apply.

In an eye-tracking experiment, participants watched a video recording of the dance piece "Duo" choreographed by William Forsythe [1]. 34 participants (age 24,5±3,2 years; 3 left-handed, 18 women) watched the video clip in two complementary experimental conditions: either they were instructed to just watch, or to watch and mark by key-press when the two dancers were moving in synchrony. Subsequently, participants filled out detailed questionnaires about their evaluation of the dance piece, their preferences and their own dance-related experience. Eye-tracking sample data were assigned to four categories representing dynamic focus regions: the bounding boxes surrounding the two dancers, the space between them, and the space outside. Counts for each category were compared between the conditions (free watching vs. marking sync) for the entire video and for individual sections, and analysed with reference to the questionnaire data (preference, experience).

Results revealed that in the free watching condition, Dancer 2 received more visual attention than Dancer 1 ($t=-3{,}301$; $p=0{,}002$), but this difference was not found in the marking sync condition, and could not be explained by personal preferences (according to the questionnaires). In the marking sync condition, spectators in general focused more often between the dancers ($t=-3{,}176$; $p=0{,}003$) and switched more often between the dancers than in the free watching condition (towards Dancer 1: $t=-3{,}403$; $p=0{,}002$; towards Dancer 2: $t=-3{,}012$; $p=0{,}005$), with most participants showing primarily one or the other pattern.

When instructed to mark the dancers' synchronicity, participants' visual attention clearly deviated from the free watching condition, in which they preferentially followed one of the dancers. The observation that individual participants applied either more frequent switching or more focusing between the dancers in the marking sync condition points towards different task-related strategies for monitoring dancers' togetherness. The situation of two dancers engaging in a danced conversation without external cues or pulse is not only relevant in the context of dance, it also has the potential to shed a new light on entrainment, joint action, joint attention, nonverbal communication, and social interaction.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Efficient Communication through Attentive Speaking

Hendrik Buschmeier, Stefan Kopp*

In dialogue, problems in understanding are resolved through mechanisms such as clarification and repair. Listeners provide feedback (verbal/vocal signals, e.g, *hm*, *uh-huh;* head gestures; facial expressions) to unfolding utterances, which speakers may immediately take into account by adapting their ongoing language production. Feedback is important for efficient communication, as emerging problems can be solved before they become critical, or production can be discontinued upon understanding. Endowing artificial conversational agents – dialogue systems, virtual agents, robots – with such intelligently interactive means of communication has the potential to make them more natural and efficient.

Previously, we presented cognitive/computational models for interpreting listener feedback through probabilistic mental state attribution, incrementally adapting ongoing utterances to this attributed state, and eliciting feedback when necessary [1]. We showed that participants in an interaction study with such an 'attentive speaker agent' provided natural feedback and noticed that it was attentive and adaptive [2].

Here we present results investigating whether understanding in interaction with such an agent is reached more efficiently than with conversational agents that are not attentive to their interlocutors' needs. Participants engaged in an information presentation task with one of three embodied agents: the *attentive speaker* agent (AS), a lower-bound baseline agent that did *not adapt* to participants' needs (NA), and an upper-bound baseline agent that always *explicitly asked* participants whether it should repeat information (EA). We measured costs of the interactions in terms of duration, and performance in terms of understanding (operationalised via recall).

As expected, interactions in target condition AS were shorter than in condition EA and longer than in condition NA. Similarly, participants' performance in target condition AS was lower than in condition EA and higher than in condition NA. Analysing the efficiency (ratio of performance to costs) of the interactions, we found that interactions with the attentive speaker agent were more efficient than interactions in condition EA (factor 1.18), but less efficient than interactions in condition NA (factor 0.55).

The results show that taking user feedback into account in human–agent interaction and adapting to it makes communication more efficient than when explicitly ensuring users' understanding. Not adapting was even more efficient, but found to be less helpful and cooperative [2]. Being able to speak attentively can thus be regarded an important step towards natural, smooth, and efficient interaction with artificial conversational agents.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Predicting financial risk judgment performance with heart rate variability

Caterina Bérubé, Svetlana Ognjanovic, Christoph Hölscher*

This study aimed to investigate how cognitive workload (hereafter called workload) can be captured by heart rate variability (HRV; i.e. the fluctuation in time of the intervals between consecutive heart beats) and affect financial risk judgment performance. HRV has been observed to be sensitive to difficulty variation in cognitively demanding tasks (e.g. [1]). However, to current knowledge, there's no evidence of the effect of workload on financial risk judgment performance, nor on an association between task difficulty and HRV.

Workload was manipulated through a dual-task paradigm. The primary task required participants to choose the riskier stock in a full-pairwise forced choice task. Each alternative was provided with a rich layout of information, varying in usefulness. The secondary task consisted of an auditory letter N-Back task, i.e., listening to an auditory sequence of letters and responding each time the same letter as N letters earlier was heard. Workload was manipulated through secondary task difficulty: a 2-Back task (high Workload) was compared to a 0-Back task (low Workload).

As there are several potential indirect indicators of a stock's riskiness and individual opinions on which to rely most differ [2], we assumed a performant judgment to remain relatively consistent. Therefore, we measured judgment performance with choices transitivity percentage [3]. Finally, we measured individual workload with HRV during a 5 minutes relaxing video (i.e. Baseline HRV) and in the first 5 minutes of the task (i.e. Task HRV), and with a self-reported assessment (i.e. NASA – TLX) [4].

The workload manipulation alone didn't affect any measured variable. Given the between-participants design and NASA-TLX scores relatively high in both groups, task difficulty manipulation may have been insufficient to differentiate the experimental groups. In other words, the heterogeneity in individual workload may have outweighed group workload. In fact, when regressing both the workload manipulation and measures of workload on choices transitivity, Task HRV seems to be able to predict choices transitivity (alone and in interaction with NASA-TLX and Workload). These results suggest that workload, when considering interindividual heterogeneity, could affect risk judgment performance. Moreover, HRV seems to be a good candidate as measure of workload in the financial risk judgment domain.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Intrinsic sequences in the hippocampus for spatial navigation and episodic memory

Sen Cheng, Mehdi Bayati, Amir Hossein Azizi*

The mammalian hippocampus is involved in two seemingly disparate functions: episodic memory of personally experienced events in humans and spatial representation in rodents and other species. However, the mechanisms underlying these functions, especially their commonalities, remain unclear. We present new computational modelling results, which suggest that sequence generation in hippocampal subregion CA3 is the key to both functions of the hippocampus.

According to our CRISP (Content Representation, Intrinsic Sequences, and Pattern completion) theory [1], the hippocampus stores neural sequences that represent episodic memories. CA3 intrinsically produces temporal sequential activities through its recurrent connectivity. To store episodic memories, intrinsic CA3 sequences are hetero-associated with sequences that are driven by sensory inputs. Our studies reveal that the accuracy of sequential retrieval depends critically on both the dynamics of CA3 and hetero-association through the hippocampal circuit. Specifically, the CA3 dynamics generating the intrinsic sequences has to be robust to noise and the feedforward pathway EC-CA3-CA1-EC can perform a fair amount of pattern completion. Furthermore, the accuracy of sequential retrieval depends on the correlations in the inputs that are to be stored by the network. Our results emphasize the importance of studying the entire hippocampal loop when investigating the neural mechanisms of memory storage and retrieval.

Sequential activity also plays an important role in spatial behaviors. During running, the local field potential in the hippocampus exhibits theta oscillations, whose phase modulates the activity of place cells. This modulation, called phase precession, leads to the activity of place cells occurring in a sequential order within a theta cycle. Even when the animal is not moving, place cells are (re-)activated in a sequential order that reflects the sequence of the animal's prior locations or the upcoming trajectory. We can account for replay and theta sequences in a variety of different experimental conditions within a single model of CA3 based on 2-d continuous attractor dynamics and spike-frequency adaptation. This model can generate enhanced replay after exposure, theta sequences, and phase precession.

These sequential phenomena now have to be reconciled with spatial response of place cells, which is difficult since sequences are always progressing whereas place cell responses can repeat (when the animal returns to the same location). Our preliminary results suggest that spatially selective, feedforward inputs can drive place cell responses in CA3 while, at the same time, intrinsic CA3 dynamics drives sequential activity. Together, our results suggest that a common feature, intrinsic sequences in CA3, is crucial for accounting for episodic memory and spatial representations in the hippocampus.

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Cognitive Neuroscience, Wednesday, Sep 5, 10:30-12:00

A Visual Language for Solving Bongard Problems

*Stefan Depeweg, Constantin A. Rothkopf, Frank Jäkel**

More than 50 years ago Bongard introduced a set of 100 vision problems as a test-bed for visual pattern recognition [1]. Although these problems are well known in the cognitive science and AI communities only moderate progress has been made towards solving a substantial subset of them. The approach we present here extracts standard visual features as a basic visual vocabulary. We introduce a formal language that allows representing complex visual concepts and relations using this vocabulary. Finally, using Bayesian inference on the space of concepts formulated in this visual language, we compare the concepts with high posterior probability to the solutions formulated by Bongard himself when designing his problems. We find good agreement for a sizable fraction of the problems.

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Thinking and Reasoning, Tuesday, Sep 4, 15:30-17:00

Vocabulary Learning Improves with Interactive Finger Gestures

Christian Ebert, Cornelia Ebert, Robin Hörnig*

We contribute to the research question whether self-performance of a learner in an interactive multi-media environment (e.g. by interacting with an object on the screen instead of listening, reading or watching alone) may have an effect on the learner's outcome (cf. [1]). We investigate this question with respect to vocabulary learning as one main precondition for the mastery of a foreign language.

In our study, we contrast text-based learning (TEXT condition) with a learning method involving a congruent finger gesture (GESTURE condition) on touch devices. In cued recall tests, we found a significant difference in recall abilities with a clear advantage for the gesture method. We take this as a confirmation for the hypothesis that vocabulary learning can be enhanced by using interactive learning methods that go beyond simple functional clicks and taps.

Thirty-six undergraduate students completed three learning sessions on each of three consecutive days (1st to 3rd day). In addition, participants worked on four online test sessions: two tests prior to the respective learning sessions on the 2nd and 3rd day, and two tests after learning was completed, one on the 4th day, and one on the 24th day to test long-term retention. The vocabulary list to be learned consisted of 44 verbs in Malagasy, an Austronesian language unfamiliar to the participants. The stimulus material for the 44 verbs consisted of the Malagasy verbs and their German translations and a short video sequence paired with a finger gesture in the GESTURE condition; the equivalent to the gesture in the TEXT condition was a tap on a button. The short video sequences showed one character prototypically performing the action named by the verb. A trigger point and a finger gesture to be performed on the touch screen, e.g. a pinch, were determined for all videos. For the 44 verbs, there was one version each for the TEXT and the GESTURE condition. The two verb versions were assigned to two lists, 22 in either condition per list. About an equal number of participants was randomly assigned to either list.

Our analysis (Generalized Linear Mixed-effects Model with a logit link function in R) revealed significant differences between consecutive testing times. Importantly, performance was reliably better in the GESTURE than in the TEXT condition, 47 vs. 41 %, irrespective of testing time, i.e., the two factors did not interact. The finding supports the conclusion that interactive finger gestures improve vocabulary learning.

[1] Schwartz R. N. & Plass J. (2014). Click versus drag: User-performed tasks and the enactment effect in an interactive multimedia environment. *Computers in Human Behavior* 33: 242-255.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Diversity in Reasoning: A Challenge for Cognitive Modeling

Lukas Elflein, Marco Ragni*

Most experiments in the psychology of reasoning are conducted with individuals. Most cognitive models aim at explaining responses given in these experiments - although not the individual response patterns of individual participants, but response frequencies aggregated across participants. Additionally, most of these models are based on very few or no parameters. Experimental observations reveal substantial diversity in human reasoning behavior. We claim that this diversity is hard to capture by small aggregate-level models. We support this claim by analyzing two exemplar state-of-the-art models from the Bayesian Rationality framework.

The first example is the Probabilistic Model [1], which describes human reasoning about a conditional '*if p, then q*' with the conditional probability P(q|p). It uses three fitting parameters, which we fit to aggregated data. We observe reasonably good agreement between observed and predicted aggregated data. However, the model does not reproduce the reasoning patterns of individual humans observed in experiments. Conversely, if we estimate parameters for each reasoner individually, this distribution of parameters does not agree with the point estimate for the aggregated data. These two findings suggest that the model does not capture the relevant reasoning processes.

In the domain of syllogistic reasoning, the Probability Heuristics Model (PHM) [2] suffers from similar limitations. A systematic analysis of the model parameters shows a substantial variation in parameter values across experiments. This variation poses problems for most interpretations of the model which include capturing universal cognitive processes. A Bayesian modeling approach shows that the parameters are dispersely and multimodally distributed.Sampling participants from this distribution plausibly leads to the observed variation in parameters optimized for aggregated data.

Thus, while substantial diversity in behavior is present in at least two classic domains of reasoning, models in the Bayesian Rationality framework fail to account for this diversity. Most other state-of-the-art cognitive models are based on the very same methods, i.e. small numbers of parameters fitted using aggregated data, which are supposed to describe homogeneous reasoning processes. Extrapolating from the problems observed in the models analyzed here, similar limitations are likely to appear in other cognitive models. We recommend

(1) a grounding of models in individual instead of aggregated data

(2) explicitly including diversity in reasoning into models.

One promising venue is to construct models based on their ability to predict participant's responses given a history of responses from the very same participant.

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Thinking and Reasoning, Tuesday, Sep 4, 15:30-17:00

Does my GPS want me to turn now or at the next intersection? Testing the ability to detect mismatches between the map view and the egocentric view of intersections.

Julia Frankenstein, Constantin Rothkopf*

Introduction: Occasionally humans get lost even with available map information, or while using car navigation systems. Even though these systems provide instructions on when to turn, instructions are given in advance and especially in situations with more turning options, humans may need to compare the map information given to the intersections faced. For that, the simplified and detail-reduced top-down view of a map has to be compared to the environment perceived in driving perspective. Using the example of x-intersections, we aimed at quantifying to which extent humans are able to perceive a mismatch between a map and the environment. Furthermore, we wanted to find out whether a greater ability in detecting mismatches is related to higher spatial abilities.

Method: We collected data from 52 participants, who simultaneously faced a map and an intersection from walking perspective in virtual reality on a computer screen. The map and the intersection corresponded completely or differed in one street angle. Participants were asked to decide whether the given map view showed the intersection or not. For every participant, we identified the individual angle deviation necessary to perceive a mismatch between map and VR-environment. This data was correlated to performance in the Spatial Orientation Test (Hegarty & Waller, 2004) and self-reported spatial orientation abilities (FRS, Münzer & Hölscher, 2011).

Results & Discussion: Street angle sensitivity did not differ between males and females. The average angle deviation to detect a mismatch was 17.7 deg (SD = 7.79) for women (n = 29), and 18.1 deg (SD = 10.62) for men (n = 21). Only for male participants a higher street angle sensitivity correlated with a higher score in the FRS scale ”cardinal directions”. Further research should address how these values change with intersections’ geometry (e.g., T-intersections), complexity of the environment or map, and stress induced by complex driving situations.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Gamma oscillations gate synaptic plasticity in the cerebral cortex

Ralf Galuske, Matthias Munk, Wolf Singer*

Use dependent changes of synaptic transmission must be gated in order to prevent spurious and irrelevant activity from inducing inappropriate synaptic modifications. The purpose of this study was to test the hypothesis that gamma oscillations could serve as mechanism to gate neuronal plasticity as a function of local network dynamics. We examined the effect of gamma oscillations on stimulation dependent modifications of orientation selectivity in adult cat visual cortex. To induce changes of the orientation map we paired electrical activation of the mesencephalic reticular formation (MRF) with repeated presentation of moving grating stimuli. Changes in orientation selectivity were assessed with optical recording of intrinsic signals and multiunit recordings. Gamma oscillations were determined from electrocorticograms and local field potentials. If the gratings induced strong gamma oscillations during conditioning, orientation domains matching the orientation of the conditioning grating became more responsive and expanded, because neurons with preferences differing by less than 30° from the orientation of the conditioning grating shifted their orientation preference towards the conditioned orientation. If conditioning stimuli induced no or only weak increases of gamma oscillations, responsiveness of neurons driven by the conditioning stimulus decreased. The differential effects of conditioning were not due to differences in discharge rate of cortical neurons because there was no correlation between the discharge frequency of responses evoked by the conditioning stimulus and the occurrence of changes in orientation preference. Thus, the occurrence and polarity of use dependent long term changes of cortical response properties appear to depend on the occurrence of gamma oscillations during induction and hence on the degree of temporal coherence (synchrony) of the change inducing network activity. It is proposed that this mechanism serves to gate experience dependent synaptic plasticity as a function of the match between sensory evidence and priors stored in the functional architecture of intra- and interareal cortical networks.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Defeasible reasoning in online shopping

Lupita Estefania Gazzo Castañeda, Johannes Schmid, Markus Knauff*

Defeasible reasoning describes peoples tendency to withdraw otherwise valid conclusions in light of additional information [1, 2]. For instance, when confronted with a conditional “If Jack does sports, then he loses weight” and the fact “Jack does sports” then people often refuse to conclude that Jack loses weight because they know that there are circumstances that can prevent Jack from losing weight although he does sports (e.g., bad nutrition, wrong exercises). These circumstances are called defeaters. Defeasible reasoning is essential in situations where people are confronted with new information that might require them to change their minds. A good example is online shopping. In many online shops people are confronted with product descriptions that try to convince customers to buy a product. However, there are also costumers' comments that suggest better not to buy the product. The aim of our study was to investigate defeasible reasoning and the role of defeaters in an online shopping setting. We created a fictitious online shopping portal for outdoor products and participants had to indicate their purchase intention on three occasions on a nine-point Likert scale: First, after an initial product description (e.g., “The new tent from Dwell offers the best protection against dampness [...]”). Second, after a positive costumer review containing either logically valid (modus ponens and modus tollens) or logically invalid (affirmation of the consequent and denial of the antecedent) argument forms (e.g., “I bought the tent from Dwell because I can be sure that I will be protected against humidity” vs. “It rained for three days and my tent stayed dry, which was obvious because it's a tent from Dwell”). And third, after a defeater, that could be a negative written reply from another costumer (written defeater: “Take care to buy the professional edition. The regular edition is not that rainproof [...]”), or a negative reply in form of a low star rating (visual defeater: 1 out of 5 stars). Purchase intentions increased significantly after positive reviews following modus ponens, but not after positive reviews following the other argument forms. Further, purchase intentions decreased significantly after the presentation of defeaters and especially after visual defeaters. Our findings represent a novel way to investigate defeasible reasoning in rich everyday contexts. They show the relevance of logic in argumentation [3] and also the importance of the modality (written vs. visual) of defeaters during reasoning.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

The influence of perseveration and volatility on action dynamics in color set shifting

Tobias Grage, Simon Frisch, Stefan Scherbaum*

In goal directed behavior, two opposed constraints have to be satisfied: On the one hand, one has to be able to pursue a goal against obstacles and distractions, thereby avoiding volatility; on the other hand, one has to let loose when alternatives become more attractive or the goal becomes unattainable, thereby avoiding futile perseveration. These opposing constraints have been conceptualized as the control dilemma between the shielding of goals from distraction and the shifting of goals when necessary. It is assumed that the balance between perseverative and volatile behavior is regulated by meta-control parameters which configure the cognitive system's default mode of processing [1]. To investigate these meta-control parameters, we shifted the balance either towards a perseverative or towards a volatile stance by manipulating situational demands (e.g. proportion congruency) within a color-based shifting paradigm [2].

In set shifting, two stimuli are presented in two out of three colors. Participants have to categorize the stimulus that matches the cued color. After several repetition trials, the colors of target and distracter stimuli switch according to specific rules. This task offers two effects to assess both perseverative and volatile behavior: congruency effects (i.e. faster responses for a corresponding target and distracter, indicating the strength of goal shielding) and switch-costs (i.e. slower responses after switches of the target color, indicating the strength of goal shifting [2]. We examined the temporal dynamics of how congruency effects and switch-costs are affected by situational demands via mouse tracking [3].

We hypothesized that both situational demands would affect their corresponding cognitive process positively (e.g. a high demand for perseverative behavior leads to a shift towards a perseverative stance) and that they would also affect the contrary process negatively.

However, our results showed that the latter is not the case: Both situational demands only interacted significantly with their corresponding cognitive process but not the contrary one. To put these results into perspective, we used a dynamic field modeling approach in order to identify neural parameters which convey the observed behavioral changes.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

A neural dynamic architecture for conjunctive visual search

Raul Grieben, Jan Tekülve, Stephan K. U. Zibner, Sebastian Schneegans, Gregor Schöner*

The goal of conjunctive visual search is to attentionally select a location at which the visual array matches a set of cued feature values. A large literature in visual cognition addresses many aspects of visual search [1]. Since Anne Treisman's seminal work on feature integration theory [2], the organization of visual search guided by the combination of multiple feature dimensions (or conjunctions) into a parallel and a serial stream has been a dominant theme.

Our goal is to provide a neural processing account for feature binding through space that autonomously organizes visual search without any intervening algorithm or computational abstraction. We build on earlier work [3, Chapter 8] that was based on Dynamic Field Theory [3], a theoretical framework for understanding cognition grounded in neural population activity. In the model, neural activation patterns evolve continuously in time. Decisions emerge from dynamic instabilities, in which peaks of activations arise. Sequences of such events emerge from the interactions within the neural architecture. Thus, the neural dynamics fundamentally evolves in parallel across the entire architecture, but sequential processing steps emerge under appropriate conditions.

Earlier we showed that this model can account for classical signatures of binding through space in change detection paradigms [3, Chapter 8]. Here we show that the theory can generate conjunctive visual searches and demonstrate the emergence of the processes of searching for a target object in the presence of distractor items. The particular scenario involves looking at a visual scene to which a target object is added at some point. The task is to find a visually matching object. All processing steps emerge from the time-continuous dynamics of the neural architecture, which is capable of autonomously exploring the visual array by attentionally selecting locations, memorizing feature values associated with those locations, and visually searching for cued feature conjunctions.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Investigating Michie's Operational Effectiveness Criterion of Machine Learned Models

*Sonja Grünauer, Ute Schmid**

In the early days of machine learning Michie [1] introduced two orthogonal dimensions to evaluate performance – predictive accuracy and comprehensibility. He proposed to characterize comprehensibility as operational effectiveness – meaning that the machine learning system can communicate the learned hypothesis (model) to a human, whose performance is consequently increased to a level beyond that of the human studying the training data alone. Later definitions narrowed their focus to measures of accuracy. As a consequence, statistical/neuronal approaches have been favored over symbolic approaches to machine learning, such as inductive logic programming (ILP).

In a previous paper we provided an operational definition of comprehensibility in the context of ILP together with an empirical demonstration of Michie's operational effectiveness for logic programs in the context of a fictitious chemistry domain [2]. The domain is isomorphic to the family domain which is often used in introductions to logic programming. The learned models were presented as Prolog programs. This presupposed that participants had to be knowledgeable in logic programming.

To examine whether our results are generalizable to humans with no background in computer science and Prolog, we conducted a third study. Participants were 26 students of humanities. They were presented with the chemistry domain of the previous study. However, training data and learned rules were given in a generally understandable way. The cover story was that different pairs of substances (named a, b, c, and so on, corresponding to first names in the family domain) were mixed and were tested whether they showed a certain property 1 (father in the family domain) or another property 2 (mother in the family domain). Afterwards, participants were told that for a selection of these mixtures it has been tested whether their composition is exothermic. They were presented with a selection of 5 positive and 5 negative examples with respect to their classification as exothermic (rule grandparent in the family domain). Next, participants were randomly assigned to one of two conditions: In one condition participants first had to classify - only based on the training data - new mixtures as exothermic or not. Afterwards, both groups were presented with the learned rules and had to classify a second set of mixtures. Results show a significant improvement when the rules have been presented, demonstrating that Michie's operational effectiveness criterion can be met by the symbolic machine learning approach ILP.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Discovering Rational Heuristics for Risky Choice

Sayan Gul†, Paul M. Krueger†, Frederick Callaway†, Thomas L. Griffiths, Falk Lieder†*

How should we think and decide to make the best possible use of our precious time and limited cognitive resources? And how do people's cognitive strategies compare to this ideal? We study these questions in the domain of multi-alternative risky choice using the methodology of resource-rational analysis.

To answer the first question, we leverage a new meta-level reinforcement learning algorithm to derive optimal heuristics for four different risky choice environments. To achieve this, we first formalize the problem of deciding how to decide as a meta-level MDP [1] and then approximate its optimal solution using our recently developed Bayesian meta-level policy search method [2]. We find that our method rediscovers two fast-and-frugal heuristics that people are known to use, namely Take-The-Best and choosing randomly, as resource-rational strategies for specific environments. Our method also discovered a novel heuristic that combines elements of Take-The-Best and Satisficing (SAT-TTB).

To answer the second question, we use the Mouselab paradigm to measure how people's decision strategies compare to the predictions of our resource-rational analysis. We found that our resource-rational analysis correctly predicted which strategies people use and under which conditions they use them. Participants used the previously unnoticed SAT-TTB heuristic discovered by our method more frequently than any other heuristic; just as our resource-rational analysis had predicted. Overall, people adapted their strategy use to the structure of the environment in accordance with the predictions of our resource-rational model: The frequency with which people relied on fast-and-frugal heuristics (TTB, SAT-TTB, SAT, or random choice) decreased significantly from 73% on low-stakes problems to 40% on high-stakes problems as people switched to more effortful strategies. Furthermore, people used TTB and SAT-TTB primarily when one outcome was much more likely than the others. However, people's strategy choices did not change radically enough with the stakes and dispersion to be completely resource-rational. Overall, people's decision operations were about 88% as resource-rational as they could possibly be. A formal model comparison confirmed that our resource-rational model explained people's decision strategies significantly better than the Directed Cognition model of Gabaix et al. [3].

Our study is a proof-of-concept that optimal cognitive strategies can be automatically derived from the principle of resource-rationality. Our results suggest that resource-rational analysis is a promising approach for uncovering people's cognitive strategies and revisiting the debate about human rationality with a more realistic normative standard.

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Judgment and Decision Making, Tuesday, Sep 4, 10:30-12:00

Visual imagery in human reasoning

Kai Hamburger, Markus Knauff*

Visual mental imagery is the subjective experience of seeing objects/events in front of the 'inner eye', although they are not present. Research indicates that visual images (1) help to remember what has been experienced in the past or when objects need to be inspected or manipulated, and (2) are correlated with neural activity in early visual cortices, demonstrating an overlap between visual imagery and visual perception [1]. However, visual imagery can also disrupt cognitive processes and impede thinking, known as the *visual impedance effect* [2].

In the first part of this contribution we describe the *visual impedance effect* and some related findings [3]. For instance, we show that congenitally blind participants –who do not experience visual mental images– do not show the *visual impedance effect* in reasoning in comparison to healthy control subjects [4].

In the second part of the contribution we present a current *transcranial magnetic stimulation* (TMS) experiment [5]. The major question was: What happens if the construction of visual images in primary visual cortex becomes more difficult during reasoning? Ten participants solved 36 relational reasoning problems that varied in their imageability. For instance, inference problems based on relations such as "cleaner-dirtier" are *easy-to-visualize*, while problems such as "smarter-dumber" are more difficult to visualize mentally. While solving the problems, eight 10Hz pulses were either applied to primary visual cortex (V1) or a control site (Vertex). With the *easy-to-visualize* problems participants made less reasoning errors under V1 stimulation than under Vertex stimulation. The *difficult-to-visualize* problems did not show such an improvement of reasoning accuracy during TM stimulation of V1.

The results of our study suggest a causal link between mental imagery, primary visual cortex, and reasoning for visual problems. They also suggest that the disruption of visual images in V1 can facilitate reasoning. This challenges the classical view that visual mental imagery helps people to reason accurately.

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Thinking and Reasoning, Tuesday, Sep 4, 15:30-17:00

Low-dimensional feature extraction of neural activity in primary visual cortex

Kilian Heck, Daniel Hofmann, Mathias Peter, Ralf Galuske*

In primary visual cortex, visual stimuli evoke specific spatiotemporal activity patterns. These can be visualized at high resolution using optical imaging and voltage-sensitive dyes (VSD). The response activity shows high degrees of variability over different trials. It has been hypothesized that this may reflect non-evoked ongoing cortical activity, which was formerly thought to be randomly distributed noise. However, it seems that ongoing activity displays spatial resemblance to evoked activity patterns [1] [3]. This might contribute to internal processing of visual input and may rely on intra-and interareal interactions [2] [6]. It is still relevant in neuroscience to elucidate, how this variability emerges and whether it is linked to changes in functional brain states.

An important prerequisite for answering these questions is to clearly define characteristics of brain states in a low-dimensional space. To this end, we extracted neural activity patterns from noisy data based on high-dimensional VSD image series by using a constrained nonnegative matrix factorization framework [4] adapted to VSD data. Several data pre- and post-processing steps were incorporated to reduce biological and technical noise artifacts beforehand. This includes an extension of an additive model of weighted noise components [5].

By applying this framework, we jointly achieved automatized dimensionality reduction, disentangling of overlapping image components and deconvolution of neural activity from the fluorescence indicator. Each component's temporal activity could then be inferred with high accuracy by using low-ordered autoregressive models.

Our results allow for the further and causal analysis of ongoing and evoked interactions. This will lead to a better understanding of neural coding strategies.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Application of Recurrent Neural Networks on fMRI and EEG Timeline Data in Music Cognition

Maria Heinze, Rainer Goebel, Frieder Stolzenburg**

During the hearing process in ear and brain, an acoustic stimulus, e.g. a musical harmony, is transformed in a highly non-linear way. This can be studied by comparing the frequency spectrum of the input stimulus and its response spectrum in the (sub-)cortical auditory processing stream. In our research, we will examine human perception while hearing selected tones, some of their integer fractions, as well as musical dyads, triads, and their inversions.

With electroencephalography (EEG), the frequency spectrum of the brain responses will be analyzed [3], considering in particular musical dyads and triads as stimuli. The hypothesis is that the brain adds tones to the input spectrum, namely the periodicity pitch [4] which is related to the missing fundamental frequency of the given musical harmony. Combining EEG with functional magnetic resonance imaging (fMRI), the corresponding activated brain regions will be localized and the coding principles in auditory brain areas be investigated. [2] claims that there is a two-dimensional tonotopic map in the brain representing pitch and periodicity. [1] models fMRI responses in the human auditory cortex as a function also in two dimensions, namely the sounds' perceived pitch height and salience. Presenting every stimulus in two different lengths (0.5s and 2.5s), each suited for one of the investigation techniques, will lead to more information from EEG curves and fMRI scans.

The overall goal is to develop a model how the human brain perceives and processes musical sounds. The prediction of this behavior will be performed by recurrent neural networks. By analyzing the transition matrices of the networks, they are able to predict the periodicity pitches. In [6] it is demonstrated that artificial neural networks with $2n$ neurons already can model and analyze a complex harmonic sound, consisting of n frequency components. Thus, recurrent neural networks provide a computational basis for musical harmony perception with periodicity detection as main ingredients. Here, the most important factor during the neural transformation for periodicity detection in the brain seems to be the spiking of neurons with a uniform, limited amplitude [5].

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Sources of variability in eye movement sequences

*D. Hoppe, C. A. Rothkopf**

Variability is inherent to all actions and various sources have been found including fluctuations in the internal states of the subject, past experiences, the current level of attention, as well as physiological processes in the brain. However, little is known about variability in temporal human visual behavior. While spatial variability, for example, endpoints of saccades, is straightforward to measure, investigating the connection of variability and environmental dynamics is more complicated due to dealing with action sequences instead of single actions.

In this study, we fill a gap in the eye movement literature by investigating goal-directed eye movements in a changing environment with controlled dynamics. This includes simultaneous demands on spatial and temporal control of gaze. In particular, we study the influence of task characteristics on behavioral variability. To this end, we developed a monitoring task where three spatial locations with independent dynamics were monitored over time in order to detect an event. Crucially, we designed the stimulus dynamics in a way making it possible to present the same stimulus dynamics repeatedly while preventing learning effects. Using this experimental paradigm we investigated the following questions: 1) How do humans decide when to make a saccade to a new target in a dynamic environment? 2) How do humans determine where the next saccade is made to? 3) How are task properties connected to behavioral variability?

Our results show that humans are capable of scheduling eye movements in accordance with the stimulus dynamics. The proportion of eye movements targeted at a specific location was affected by the probability of an event occurring at that location. These results suggest that humans can execute temporal eye movement plans following dynamic environmental demands. They are able to monitor multiple changing locations and detect events by repeatedly moving their focus to relevant spatial locations. Further, gaze sequences were similar across subjects. We developed a computational model for our monitoring task, that was able to reproduce key characteristics of our human data. In particular, the results show how external environmental dynamics and task-related rewards guide eye movement sequences. Crucially, our model reflected properties of the eye movement variability found in our data and therefore quantitatively relates behavioral variability to properties of the task.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Modeling nonverbal communicative signaling in predictive social motorics

Sebastian Kahl, Stefan Kopp*

In successful social interaction, people dynamically understand, predict, and influence mental states and actions so as to enable efficient and interactive grounding of shared meaning. We effectively query our communication partners and depend on their reciprocity to grasp their state of knowledge. Communication errors are common, informative and important. Through them we get bits of information that can guide our communicative acts towards our communicative goal. Our computational model of the dynamics within the social brain and between social agents is based on hierarchical predictive processing. We want to describe how our previous modeling approach is advanced by modeling nonverbal communicative signaling, i.e., the strategic alteration of one's own action kinematics to better achieve a communicative goal [1].

In earlier computational models we showed how the interactive grounding process between two virtual agents can work through reciprocity alone. This process was not efficient, resulting in many repetitions. To increase communication efficiency we focused on the process of self-other distinction in lower levels of the sensorimotor processing hierarchy, i.e., had an action been caused by oneself or another agent. Modeling this distinction already low in the sensorimotor hierarchy resulted not only in the ability to decide who performed perceived actions but more importantly how [2].

Our model of communicative signaling works with knowledge gathered during the interaction by matching perceived actions with our predictive processing hierarchy's representations of action schemas. Each action schema can be produced by many similar action sequences. Especially informative are (1) the beliefs held about the communication partner and (2) the specific knowledge which sequence of actions led to a communication error, i.e., how the action schema was produced. Based on this information the communicative signaling model selects an action sequence for the next communicative act that will be most distinguishable from the sequence that previously led to a communication error.

We propose a model of communicative signaling in a predictive sensorimotor system using information from reciprocity and self-other distinction. This model may help to shed light on how we communicate efficiently strategically selecting easier to disambiguate communicative acts. Our modeling approach focuses on iconic gestures but we speculate that this approach of strategic action selection may underlie many different signaling modalities.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Cogito, Ergo Sum? About Self-Other Discrimination and Man-Robot Cooperation

Karl Theodor Kalveram, Dimitri Penner, Markus Hessinger, André Seyfarth*

"Nothing in Biology Makes Sense except in the Light of Evolution" [1]. Applying this famous saying to self-awareness and self-consciousness, we ask, what are such personal experiences in aid of? Consider them as epi-phenomena of the human capability to interact with one another co-equally! Just this respecting others' autonomy seems providing a surplus of biological fitness over those individuals who only egoistically struggle for life. Keeping partners in co-operation and preventing competition while operating a common task *is* a tricky problem, but obviously solved by evolution. The concept of **paired abstract automatons** [2], the actors of which we call **Self** and **Other**, is used to rope in interactive behavior and to quantify autonomy (an abstract automaton is understood as an actor equipped with input, output and internal states, intentions included, which determine the output together with the input). Co-equal interaction requires each actor to shape the partner's output towards its own intentions. To achieve cooperation that avoids mutual blocking, both must coordinate their intentions and outputs accordingly, but can rely solely on sensory signals to communicate. Referring to mechanical **Controller-Plant Systems** [3], which apply **Adaptive Inverse Control,** suggests a solution: as a "bycatch", the inbuilt plant's inverse dynamics model enables the controller to distinguish, whether the plant complies with the controller's commands or deviates from them. The latter indicates that the plant wants realizing intentions of its own, that is, claiming autonomy itself. A co-operatively reacting controller then would leave control to the plant and not insist on overriding the plant, but claim role reversal after a while. These considerations suggest that breaking a rule, which a pair's actors had previously agreed upon, and rule breaking recognition constitute the **syntax** of mutual signaling changed intentional states. **Semantics** then specifies the meaning, and **pragmatics** selects suitable behavioral actions leading for instance to "**intermittent autonomy**" as adumbrated above – in humans attended by self-awareness as symptom. A preliminary **experiment** with a drilling task, executed by either a robotic exoskeleton [4], stand-alone subjects, pairs of subjects, or exoskeleton-subject pairs [5], revealed the subject-subject pairs as best-performers, not the robot-aided subjects, probably because the robot, applying PID-control that lacks rule-breaking recognition, enslaved the subject and impeded a surplus.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Modelling Affordance Based Saliency Maps

Ashima Keshava, Thomas Schüler, Peter König*

Saliency Maps model overt attention based on stimulus dependent features such as color, contrast and orientation [1]. With the advent of deep neural network models of salience such as DeepGaze [2], DeepFix[3] and SALICON [4] great strides have been made in setting saliency model benchmarks. Despite this, these saliency models underperform when describing salience of higher level concepts in an image such as object of gaze, object and location of action, etc. [5]. In order to address this, we propose a model to predict salience of particular affordances in a given image.

For the purpose of this project we look at goal directed behavior in the context of Gibson's affordances. We specifically include affordances such as grasp, cut, scoop, contain, pound and wrap-grasp of common household tools. So, given a particular task (e.g. grasp), a saliency map would highlight the object parts in a scene with the said affordance that would fulfill the task requirements. Alternatively, in a free viewing task, due to a lack of a specific task description, the map would be represented as an average over all affordances in the scene weighted also by perceptually salient features such as brightness, contrast, etc. In this case, we hypothesize that objects that have multiple affordances would be more 'salient' compared to others. Inspired by this, the aim of the present study is to model a saliency map given several objects with various affordances.

We use a VGG-16 Fully Convolutional Network [6] on the UMD dataset [7] to create feature maps of the various affordances of the images of tools. For each image we produce a combined map which predicts the regions in the image that have a particular affordance.

Here, we present an architecture that builds upon classical saliency maps that are based purely on bottom up perceptual signals. Additionally, these maps not only model which objects are more salient for a given task but also which parts of the object are fixated on. Consequently, this project lays the groundwork for further research into task relevant signalling in target selection.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

The Psychological Reality of Verb-Argument Constructions: A Visual World Eye-Tracking Study

Simon Kirsch, Lars Konieczny*

We will present a Visual World-Study investigating how verb-argument constructions influence on-line comprehension.

In Construction Grammar, argument structures are considered autonomous constructions, i.e. form-meaning pairings, independent of their lexical content [1]. Earlier research has shown that argument structure is a valid factor in a variety of off-line interpretation tasks [2,3]. However, it remains unclear whether argument structure is processed automatically in sentence comprehension or considered only if needed for a particular off-line task.

We invented 20 denominal verbs (e.g. "to basket"), which do not have any systematic dependencies on specific constructions, along the lines of [2]. Each of these verbs was embedded in a *resultative* (1) and a *caused-motion* sentence (2).

(1) Petra baskets the snowman apart.

(2) Petra baskets the grapes into the tank.

40 participants heard one sentence type per verb, while looking at three scenes, depicting *i.* a *resultative* event, *ii.* a *caused-motion* event, and *iii*. an unrelated distractor event. Additionally, we varied whether the matching scenes depicted the exact content of the spoken sentence arguments (e.g. *snowman* or *grapes*), or just events that where compatible with the sentence's construction type but with no overlap in lexical content, e.g. someone tearing a sheet of paper to pieces (*resultative*), or someone shoving a ladder through a window (*caused-motion*).

We found reliably more looks to the compatible scenes than to incompatible scenes for both construction types in a time window of 500 to 1500 msec after the onset of the disambiguating sentence segment (e.g. *apart* or *into the tank*) in trials with construction depictions lacking lexical overlap. This result suggests that de-lexicalized construction knowledge is applied during sentence processing at an early stage of comprehension. The study therefore provides evidence indicating that abstract argument structure constructions bear meaning independent of their lexical instantiations.

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Language and Communication, Wednesday, Sep 5, 15:30-17:00

Influence of Segmentation on Movement Primitive Representations under Naturalistic Conditions

Benjamin Knopp, Moritz Schubert, Dominik Endres*

The idea that complex entities are composed of simple elements is very powerful, and has been successful in Physics (Atoms), Biology (Genes) and the toy industry (Lego®). In motor control, the term "Movement Primitives" (MP), refers to such elemental building blocks of complex movements. We hypothesize that MPs do not only simplify control, but also perception, as suggested by common-coding theories [1]. This enables us to investigate perceptual consequences of MPs, e.g. their boundaries in time [2].

We are establishing a Bayesian framework for automatic segmentation and simultaneous MP extraction. For now, it allows for comparison of segmentation approaches. We compared human perceptual segmentation with minimal velocity segmentation, which is a popular heuristic for human movement segmentation. To carry out this comparison, we recorded an actor performing natural tasks in a fairly unconstrained manner. These recordings were used to generate 70 video clips containing selections of the recording to 12 participants. They were instructed to segment these clips into non-overlapping time intervals according to perceived boundaries. We then used the movement data for extraction of MPs, according to both the perceptual segmentations and the minimum-velocity heuristic. We specify the MP model and compute an approximation to the marginal likelihood. We investigated a simple Principal Component MP model with Bayesian Information Criterion (BIC), and Akaike Information Criterion (AIC) as model scores.

According to the BIC score, human participants choosing a coarse segmentation provided the best representation of data using temporal MPs. AIC did not yield any useful results. We verified that minimal velocity segmentation is not useful for predicting perceptual segmentation with a hit rate analysis.

Currently, we are extending our framework by adding additional MP definitions to the comparison, such as Gaussian process latent state space models [3]. Moreover, we will experiment with Bayes-optimal segmentation instead of heuristics, using our Bayesian binning approach [4]. The demonstration of the Bayes-optimality of human motor perception would add evidence for optimal feedback control (OFC) as a normative motor theory [5], because OFC is only sensible if perception is optimal, too.

This work was funded by the DFG under IRTG1901 'The Brain in Action', and SFB-TRR135.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Learning human discounting from observational data

Heinz Koeppl, Constantin A. Rothkopf

There is an ongoing controversy among cognitive scientists regarding the discounting characteristics in human preferences and decision making. Although most of the underlying Markov decision process theory used by AI researcher deploy exponential discounting, there is little experimental evidence that humans discount exponentially. Indeed, several studies report that hyperbolic discounting is most congruent with the acquired trial data. In contrast to exponentials, hyperbolic discount functions lack the memoryless properties leading to irrational or incoherent decision making such as preference reversal, e.g., an agent may prefer one Euro today over two Euros tomorrow but reverts his choice if both reward options were just shifted for a week. Recent studies have also shown that humans can adapt their discounting based on the particular trial scenario. This raises the question of how humans discount in natural situations and whether this discounting can be inferred from uncontrolled behavioural data.

It is well known that the optimal policy for a finite trial period without discounting but with uncertain termination time coincides with the one for an unbounded period and exponential discounting. Motivated by this fact, we start out by mathematically analysing different trial scenarios and uncertainties and determine the optimal discounting function for a rationally planning agent. For instance, we show that uncertainty in the mean termination time for an exponential trial period naturally leads to hyperbolic discounting for a rational agent. The analysis yields a rather general parametric family of discounting functions that we subsequently use to devise a new type of inverse reinforcement learning (IRL) framework, where instead of the reward function, one infers the parametric form of the discounting function. In line with traditional IRL framework, the method requires solely observational data of the agent together with the functional form of the reward. To this end, we discuss the problem of inferring reward and discounting function jointly and show that it generally leads to deficiency.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

What does the EEG reveal about how athletes process head fakes in basketball?

Dirk Koester, Christoph Schütz, Iris Güldenpenning, Thomas Schack*

Processing of gaze direction in basketball can be influenced strategically, especially for frequent head fakes (i.e., contradictory gaze/pass direction; [1, 2]). It remains unknown how processing changes and whether (motor) expertise plays a role. Using event-related potentials (ERPs), automatic processing of gaze and pass direction (basketball) were investigated, incl. strategic suppression of gaze. We aimed to compared athlete data with available novice data, specifically regarding attention demanding (P3 component of the ERP) and conflict monitoring resources (N2 component; [3]).

Sixteen athletes judged the pass direction of an opponent (target picture) in a subliminal priming experiment (prime duration: 17 ms). Both pass and gaze directions were manipulated independently (left vs. right for primes and targets; repeated measures, 2x2 design). Target pictures showed either always a head fake (block A) or never a head fake (block B; pass and gaze always compatible). Optimal processing should suppress gaze information in block A but not in block B. Subsequently, prime detection was tested.

Preliminary analyses show prime recognition at chance (54 %), suggesting automatic processing. Analyses of reaction times yielded a main effect of pass congruence in block A, $F(1,15) = 45,6$; $p < .0001$, and in block B, $F(1,15) = 20,9$; $p < .001$. A main effect of gaze congruence was found in block B only, $F(1,15) = 9,1$; $p < .01$. The ERPs (electrode placement: 10-20-system) suggest an N2 effect in block A (increased amplitude for incongruent gaze, 200-300 ms, P3, P4; $Fs(1,15) > 6,6$; $ps < .05$). However, there was only a P3 effect in block B (increased amplitude for incongruent pass (between prime and target), 400-500 ms, PZ; $F(1,15)=4,7$; $p<.05$).

An incongruent pass direction (prime) delays target evaluation (pass direction). Also, an incongruent gaze delayed pass evaluation but only in block A. Hence, the processing of gaze direction can be suppressed by basketball athletes strategically, consistent with novice data. The ERP results suggest that athletes differ qualitatively from novices in their processing of gaze. If targets show head fakes (A), athletes rely on rather automatic processing of pass direction (N2 effect), but without head fakes (B), the P3 effect suggests a focussed, controlled processing of pass direction. Compared to novices, the data suggest that (motor) expertise impacts the processing of head fakes (gaze information).

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

The Role of Alternative Constructions for Quantifier Scope Ambiguities: A cross-linguistic study

Lars Konieczny, Barbara Hemforth*

We will present a series of questionnaire experiments, showing that French, English, and German differ systematically with respect to preferences of sentences that are ambiguous between a linear scope interpretation and an inverse scope interpretation of all-quantifiers and negation

(1a) Alle meine Freunde sind nicht in den letzten Marvel-Film gegangen.

(1b) All my friends didn't go to see the last Marvel movie.

(1c) Tous mes amis ne sont pas allés voir le dernier film de Marvel.

We argue that these differences are the result of differences in the grammar of the three languages. Close alternatives to (1) exist for German and English which are only compatible with a wide scope interpretation of the negation (2), thus corresponding to the inverse scope reading of (1). The parallel alternative in French may occur in very informal spoken French but it is highly marked and not available in standard French.

(2a) Nicht alle meine Freunde sind in den letzten Marvel-Film gegangen.

(2b) Not all my friends went to the last Marvel movie.

(2c) ?? Pas tous mes amis sont allés au dernier film de Marvel.

Experiment 1: We presented participants (49 French, 59 English and 58 German) with 10 experimental sentences like (1a-c), simultaneously with two possible interpretations: i. linear scope interpretation: *None of my friends went to see the last Marvel movie.* ii. inverse scope interpretation: *Some of my friends went to see the last Marvel movie.* Participants had to judge how well each of the the interpretations fit the target sentence on a 5-point scale. All experiments were run on Ibex Farm, target sentences were mixed with 20 filler sentences.

French speakers showed a strong preference for inverse scope while German speakers strongly preferred linear scope. English speakers showed a slight preference for linear scope but less pronounced than German speakers.

Experiment 2: The role of alternative constructions has been shown to depend on their accessibility in the language but also in the local environment [1]. We replaced 10 of the filler sentences from Exp. 1 with sentences like *Not all packages weighed more than five pounds.* This experiment was run with 60 English speakers. The presence of the alternative construction significantly increased linear scope preferences for English speakers.

Conclusion: Our experiments show that the existence of alternative constructions as well as fine grained differences in the grammars can explain cross-linguistic differences not only in syntax but also in semantic interpretation. The particular role of the preverbal position in German main clauses as a default topic position increases the linear scope preference compared to English.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

A neural dynamic architecture autonomously builds mental models and makes inferences on them

Parthena Kounatidou, Mathis Richter, Jonas Lins, Gregor Schöner*

Suppose you are asked to "Imagine a red object to the left of a green object" and to "Imagine a blue object to the right of the red object". Creating mental models from such phrases comes naturally to us; we effortlessly form object representations and find appropriate spatial positions for these objects in the imagined scene. However, even these operations require vast cognitive abilities. Constructing mental models is particularly challenging when the phrases that describe the scene are ambiguous. For instance, in the above example it is unclear whether the blue object should be placed to the left or right of the green object. Ragni and Knauff [1] find that people solve such problems by making as few changes to an already established mental model as possible, placing new objects in free positions. They account for this behavior in abstract information processing accounts, where symbols of objects are placed on a grid-canvas.

But how may the construction of mental models be facilitated by the brain? We know that both imagining and perceiving scenes engage the brain's sensorimotor areas. This suggests that mental models share representational substrates with perception. We have previously made the substrates and neural processes of perception concrete in a model of perceptual grounding [2]. The architecture is based on dynamic field theory (DFT), a neurally plausible framework for modeling cognitive processes [3]. Here, we extend that architecture to capture how it may construct mental models and answer questions about them.

The architecture is given a sequence of phrases that activate representations of discrete concepts (e.g., red). Phrases similar to the examples above instruct the architecture to build a mental model based on continuous perceptual representations. The architecture captures findings by Ragni and Knauff [1] on how humans solve ambiguous phrases. In these cases, the imagined scene influences new objects to be placed in free positions. Once such a model has been created, the architecture can answer questions such as "What is to the left of the green object?", or "Where is the blue object with respect to the green object?" The architecture is able to give answers by activating representations of discrete concepts such as red or to the right of.

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Thinking and Reasoning, Tuesday, Sep 4, 15:30-17:00

Causal Structure of Moral Dilemmas Predicts Perceived Difficulty of Making a Decision

Barbara Kuhnert, Felix Lindner, Martin Mose Bentzen, Marco Ragni*

We introduce causal agency models as a modeling technique for representing and reasoning about ethical dilemmas. We find that ethical dilemmas, although they look similar on the surface, have very different causal structures. Based on their structural properties, as identified by the causal agency models, we cluster a set of dilemmas in Type 1 and Type 2 dilemmas. We observe that for Type 2 dilemmas but not for Type 1 dilemmas, a utilitarian action Pareto dominates the possibility of refraining from action. Based on the model, we hypothesize, that Type 2 dilemmas are perceived as less difficult than Type 1 dilemmas.

We conducted an experiment with 60 participants. Participants received well-known dilemma situations and had to rate the difficulty of making a decision between each two dilemmas. Thereby the *Runaway Trolley Dilemma* and the *Pregnancy Dilemma* represented the dilemma of Type 1, the *Boat Dilemma* represented a Type 2 dilemma [1].

The results of the participants' rating of the difficulty supports the models' predictions. As hypothesized, a forced decision between the structurally similar dilemmas *Pregnancy* and *Runaway Trolley* leads to no significant difference in the frequencies of evaluations. Participants rated the decision difficulty of these two dilemmas equally. This can mainly be explained by the dilemmas' same complexity of the formal structure. However, the questions concerning the decision difficulties between the ethical scenarios *Pregnancy* and *Overweight Boat* resp. *Runaway Trolley* and *Overweight Boat* resulted in reliable differences in the evaluation of the difficulty of the moral decision situation. In both cases, the *Boat Dilemma* was selected reliably less often as the more difficult decision situation. These results support our theory of a different formal structure and therefore a lower complexity of the *Boat Dilemma*. Once the participants have opted for a moral dilemma, their rating of the difficulty to find a decision in this decision situation is statistically equal in comparison to the rating of the participants who have chosen the other dilemma. The individual mean values show a tendency towards a lower decision difficulty in the *Boat Dilemma*.

To conclude, for Type 1 dilemmas, ethical principles predict different sets of permissible actions, and hence there is a conflict to resolve which is not present for Type 2 dilemmas. Not having such a severe conflict between the actions makes moral problems that are perceived as less difficult.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Generating Photorealistic Stimuli for Psychophysical Experiments

Bernhard Lang, Guillermo Aguilar, Marianne Maertens, Felix A. Wichmann*

The field of lightness perception investigates how humans infer surface reflectance, what we would call the “achromatic colour” or intensity of a surface in everyday life.

Stimuli used in lightness perception often consist of two-dimensional patches in different shades of grey. Such simple stimuli are agnostic towards reflectance and illumination of the patches they are made off. This may be problematic, since we are interested in the perception of surface reflectance, not the perception of the luminance arriving at the retina. Therefore we argue that to completely understand lightness perception it may be important to study lightness perception in more natural stimuli which are not ambiguous in respect to reflectance and illumination.

Advances in computer hardware and computer graphics allow the generation of photorealistic looking images of 3D scenes, where we can control both reflectance and illumination at our will. We developed a method to adjust the luminance of image regions by varying the contribution of different light sources in the scene. This is achieved by solving a linear equation system for the light source intensities.

We then use this method to generate stimuli for a scaling experiment, comparing rendered stimuli against reduced stimuli consisting of checkers on an articulated background. Preliminary results show that, at least for the still comparatively simple stimulus arrangement tested, the local surround has a larger influence on the perceptual scales than the (realistic) scene embedding.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Introducing Model Checking to Facilitate the Search for Spatial Representations in ACT-R

Vincent Langenfeld, Rebecca Albrecht, Bernd Westphal*

We present a method which enables a much more efficient analysis and comparison of ACT-R models. In ACT-R one psychological theory can computationally be expressed by a high number of alternative models. In order to understand whether the psychological theory explains human behaviour well alternative models need to be considered and compared. This is time consuming and often skipped as relevant parts of each model have to be extracted and analysed. We facilitate (statistical) model checking to reason about the whole computational space of an ACT-R model.

ACT-R [2] is a hybrid cognitive architecture combining symbol processing with sub-symbolic mechanisms. Choosing a knowledge representation is a challenging task in ACT-R: There are various ways in which task information can be translated into ACT-R knowledge (called chunks), and how chunks can be requested from declarative memory. Consider a VR-experiment were a sequence of regular intersections, each with a salient landmark and a turning direction need to be learned and later recalled. Even by including only the most essential task information, namely the colour and position of the salient building, and the turning direction, we can already think of three possible chunk representations: Represent the salient building and the turning direction in one chunk. Alternatively, we can split the information into one chunk representing the salient building and another chunk to link the turning direction to the salient building's colour or position. When the turning direction of an intersection given a salient building needs to be retrieved from declarative memory nine alternative requests are possible, ranging from an unrestricted request to a fully specified request. Resulting in 27 different models with very different quantitative and qualitative predictions concerning response times and error rates.

Practically, finding a suitable ACT-R model can be decomposed into two steps: (1) fixing a combination of chunk representations and retrieval specification and (2) adjusting the sub-symbolic parameters to predict actual quantitative data in the experiment. To enable the analysis, we translate relevant parts of the ACT-R cognitive architecture and the cognitive model into timed-/hybrid-automata [1,3]. In contrast to pure simulation the use of a model checker allows to query the model for properties like "does every computation path of the model result in a valid response", "how probable is a response" or "can a response x be observed within time t". Thus model checking enables a much more efficient search for suitable models

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Data Availability and Function Extrapolation

Pablo León-Villagrá, Irina Preda, Christopher G. Lucas*

In function learning experiments, where participants learn from sequentially-presented examples, people show a strong tacit expectation that most relationships are linear, and struggle to learn and extrapolate from non-linear relationships. In contrast, function estimation tasks where data are presented simultaneously – typically using scatter plots – have shown that human learners can discover and extrapolate from complex non-linear trends. Do people have different expectations about underlying functions in these task, or can differences be attributed to the fact that people must rely on their memories of past examples, rather than having all data available simultaneously?

In a direct experimental comparison of both paradigms, we found that differences between these tasks can be attributed to data availability. To distinguish the contribution of visual presentation from availability, we introduced a novel condition (sequential-scatter) that combined the visual features of function estimation with the sequential presentation and memory demands of function learning tasks. If differences between traditional function learning and function estimation are due to data availability rather than differences in inductive biases or visual presentation, then the performance in the sequential-scatter task should resemble performance in a matched function learning condition, as participants will have to rely on recollection of the presented data. Consistent with our hypothesis, participants' extrapolations in the function learning and sequential-scatter conditions were almost indistinguishable, regardless of the function they were trained to extrapolate (linear, quadratic, or sinusoidal). In contrast, judgments in both sequential conditions were clearly different from those in the function estimation conditions.

Finally, we examined a stronger version of our research question – what are the characteristic patterns of generalization and how are they affected by availability and functional form? Do these patterns differ systematically between conditions, or are differences due to condition-independent biases? We show that a simple memory-limited Bayesian model is consistent with human extrapolations for linear data for both high and low data availability. However, contra our expectations, our model underestimates the participants' ability to infer non-linear and non-monotonic functions, especially when data is sparse. Our results suggests that the same computational principles govern function estimation and function learning, but demands on memory should be a crucial consideration when designing experiments. While memory demands can influence extrapolation we also found that irrespective of presentation, participants picked up high-level function features. This suggest that higher-order functional properties are used when generalizing, both when data is sparse and plentiful.

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Judgment and Decision Making, Tuesday, Sep 4, 10:30-12:00

The Impact of Visual Context on the Understanding of Irony

Saskia Leymann, Verena Haser, Lars Konieczny*

Can the intended meaning of ironic language be understood directly or is it necessary to interpret the literal meaning of the utterance before re-interpreting it? Gibbs' direct access view [1] postulates that given a strong enough context ironic language can be processed as directly as literal language. In opposition Giora's graded salience hypothesis [2] states that the most salient – usually the literal – meaning will always be interpreted first, regardless of context. Research so far has produced mixed results, potentially due to the use of methods with low sensitivity to ongoing processes. It also remains unclear what constitutes a sufficiently strong context for processing irony directly in Gibbs' sense.

To address these issues we conducted a visual world study in which we used echoic mention [3] as a factor to strengthen the context. A 2x2 factorial design was implemented with irony and echoic mention as within-subject factors. 43 participants were presented with pictures stories, each a sequence of three short scenes. The first scene introduced the situation with two speakers and a person in the background who could be a target of the literal meaning of the target utterance. In the second scene two more people entered the situation. The third scene contained the target utterance. The intended meaning of the target utterance was either ironic or literal (factor irony) and was spoken or not spoken in the preceding dialogue (factor echoic mention). Utterances were the same in both literal and ironic condition to exclude effects of prosody. Participants were instructed to select the person the target utterance referred to in each trial.

Following the direct access view one would expect participants to be equally fast to look at the correct target in both the literal and the ironic condition when echoic mention is realized. Following the graded salience hypothesis one would expect participants to be slower to identify the correct target in the ironic condition, regardless of context strength. Participants performed significantly better on the selection task in the literal condition. However, when analyzing only trials in which the correct answer was given we found no overall sigificant difference in participants' eye movements between ironic and literal conditions. This indicates that while irony is more difficult to identify, the cognitive processes involved in processing it when it has been identified appear to be the same as when processing literal language.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Discovering and Teaching Optimal Planning Strategies

Falk Lieder†, Frederick Callaway†, Paul M. Krueger, Priyam Das, Thomas L. Griffiths, Sayan Gul*

How should we think and decide, and how can we learn to make better decisions? To address these questions we formalize the discovery of cognitive strategies as a metacognitive reinforcement learning problem [1]. This formulation leads to a computational method for deriving optimal cognitive strategies [2] and a feedback mechanism for accelerating the process by which people learn how to make better decisions. Previous work found that metacognitive feedback can enable people to more quickly learn to plan more when they initially planned to little and to plan less when they initially planned too much [3]. Here, we refine this approach to develop an intelligent system that teaches people optimal planning strategies. Our training program combines a novel process-tracing paradigm that makes people's latent planning strategies observable [4] with an intelligent system that gives people feedback on how their planning strategy could be improved. The pedagogy of our intelligent tutor is based on the theory that people discover their cognitive strategies through metacognitive reinforcement learning. Concretely, the tutor's feedback is designed to maximally accelerate people's metacognitive reinforcement learning towards the optimal cognitive strategy. A series of four experiments confirmed that training with the cognitive tutor significantly improved people's decision-making competency: Experiment 1 demonstrated that the cognitive tutor's feedback accelerates participants' metacognitive learning. Experiment 2 found that this training effect transfers to more difficult planning problems in more complex environments. Experiment 3 found that these transfer effects are retained for at least 24 hours after the training. Finally, Experiment 4 found that practicing with the cognitive tutor has additional benefits over simply telling people the optimal planning strategy. These findings suggest that promoting metacognitive reinforcement learning with optimal feedback is a promising approach to improving the human mind.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Mouse tracking shows behavioral signatures of spatial language grounding

Jonas Lins, Mathis Richter, Gregor Schöner*

We report a new type of evidence for processes of language understanding that operate directly on sensorimotor representations and ground language in vision. Leveraging the close link between neural systems for perception and action we use motor signatures as indicators for activation shifts that occur within visual representations.

In a novel computer mouse tracking paradigm, participants saw a spatial phrase such as ”The green item to the left of the red one”, followed by an array of twelve colored items, and moved the mouse cursor onto the target item of the spatial phrase (here, the green one). Mouse trajectories were biased toward items implicated in grounding, namely toward the reference item (here, red) and toward the distractor item, which shared the target color (here, green) but satisfied the spatial term to a lesser degree (participants were instructed to always select the item that in their opinion matched the spatial phrase best). These effects were interpreted as reflecting attention shifts during mapping from phrase to scene components. A bias into the direction described by the spatial term (here, ”left of”) was more akin to classical embodiment effects where word semantics broadly bias motor action.

In the present study, response movements followed a horizontal axis (left to right), while in a recent similar study [1], a vertical axis was used (bottom to top). The current findings are analogous to the earlier ones, showing that the effects generalize over response metrics. They also disambiguate the origin of the spatial term and the reference effect. In the earlier study, the spatial term effect occurred only for the terms “left” and “right”; in the current study, it occurred only for “above” and “below”. This indicates that the effect extends to all spatial terms but becomes observable only when acting orthogonally to the response axis. In the earlier study, the reference effect was observed only for “above” and “below”; here, it occurred only for “left” and “right”. This suggests that the reference effect occurs in all trials but can be masked by the spatial term effect.

In a broader perspective, our findings confirm that perceptual representations of visual space are closely linked to representations of motor targets [2]. More importantly, they show that processes of language understanding modulate activation within these representations, which in turn suggests that understanding language about current environments is based on ordered neural processes that establish a linkage between linguistic and sensorimotor representations.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Common Codes in Virtual Actions

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According to theories of anticipatory behavior control, the initiation of actions is inevitably tied to an anticipation of the respective sensory consequences. Classic findings obtained in response-effect compatibility (REC) paradigms [1, 2] show that response times increase if the dimensional overlap - for instance with respect to spatial location - between actions and effects decreases [3]. However, it is still under debate whether REC effects are driven by spatial compatibility between effector and effect, or by sensorimotor characteristics of the response itself. If REC effects are due to a common coding of actions and their effects in the service of motor control [4], then REC effects should be most pronounced on action-relevant dimensions. For movement control, motor commands and their proprioceptive consequences are more relevant than visual effects of the effector, hence, according to this perspective spatial compatibility should not depend on effector visibility. In contrast, if REC effects are due to redundant, spatially related, sensory signals, effector visibility should have an effect. Furthermore, correspondence between movement and effect dynamics should be more relevant than matching spatial locations of effect and effector.

To test these hypotheses, we designed a virtual reality (VR) paradigm that allows to manipulate spatial compatibility between effector and effect, as well as compatibility between motor activation and effect dynamics. In a first experiment, we replicated REC effects in VR and could show that effector visibility does not affect the size of the REC effect. Apparently, compatibility is not driven by a mere visual match between effector and effect. In a second experiment, we investigated the effects of matching movement and effect dynamics. We observed strong compatibility effects if movement and effect dynamics matched. These effects were more pronounced than typical spatial compatibility effects.

In line with the proposed action-centered perspective, our results imply that task-relevant sensorimotor dynamics play a central role in REC effects. VR setups combined with online motion capture seem well suited to probe mechanisms of anticipatory behavior control and will allow to scrutinize the sensorimotor foundations of REC effects even further.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Do you need distraction or hint in insight problem solving?

Polina Markina, Igor Makarov*

Mechanisms of insight problem solving is one of the key questions in cognitive psychology.Insight problems are characterized by the fact that in their solution the participant falls into an impasse and then suddenly find the answer. It remains unclear, how insight problems are solved: crucial point is to avoid the ill-constructed representation, to obtain new information or to «forget» something that already known? We can examine the correctness of the first assumption by using a hint [2, 4], second and third – by the distraction. In our research hint and distraction presents in the moment of the impasse – the most important part of the insight problem [3].

Therefore, our **hypothesis** was: hint and distractor in the moment of the impasse *effect* on the solution of insight problems.

Material was two matchstick tasks [1], the complexity of one was the chunk decomposition, and the second – the constrain relaxation.

Methods: participants solved one training problem and two tasks described above. At any moment, they could say that they are at the impasse.

Results and discussion: We checked our hypothesis using ANOVA: $F(2.31) = 0.47$, $p = .627$, $\eta_p^2 = 0.03$. Consequently, the results are not significant, but the experimental influence impacted the reduction in the dispersion of the solution time.

The lack of significant results may be due to the fact that in our experiment only a quarter of the participants came into an impasse. Nevertheless, most insight researchers describe an impasse like the most important part of the insight solution [1, 3]. Consequently, we suppose, in our experiment some participants incorrectly understand the term «impasse».

Thus, we are going to continue our research by improving the wording of the instruction.

Conclusion: We cannot confirm that hint and distractor in the moment of the impasse *effect* on the solution of insight problems.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

What is the relation between representations and information?

*Manolo Martínez**

I argue that the explanatory work we want representations to do can be done by structures specifiable in purely information-theoretical terms; *rate-distortion theory [RDT]* in particular.

RDT applies to situations in which information about a source is communicated over a channel with not enough rate to accommodate lossless transmission. It aims at specifying the dependence of the minimum amount of distortion between original and decoded messages on channel rate. I defend that the existence of certain optimal ways of negotiating these channel constraints is part of what we track with our representation-attributing practices.

Consider the rate distortion function for a world consisting in tosses of a fair coin. This curve has no real structure: from 0 to 1 bit, the more rate (the wider) the channel has, the less distortion you get. One may say that messages ”represent” the outcome of the coin, if one so wishes, but this gives us nothing by way of explanatory payback.

But usually there is more structure to the world that the signaling arrangement can latch onto. Representations have explanatory payback in these other cases. Consider, e.g., a world consisting of two ”natural kinds”. The essence of each kind (i.e., the parent node in each of two independent star-graph Bayes nets) is highly predictive of the presence of the whole property cluster. The rate-distortion curve corresponding to this situation has a sudden drop in its slope when the rate reaches 2 bits. This rate corresponds to one of the ”sweet spots” alluded to in the title: because properties in the world are probabilistically connected in a certain way, most of the information present in the world can be given with 2 bits.

I suggest that our representation-attributing practices are sensitive to this bit of informational structure: *A sender-receiver arrangement is fruitfully described as involving representations only if there are sudden drops in the usefulness of extra rate (”sweet spots”).*

This account helps connect several important, apparently unrelated threads in the philosophical study of representations: on the one hand, the idea that representational status depends on the existence of a many-to-one-to-many mapping between representations and its causes and effects ([1], [2]); on the other hand, the suggestion that the referents of simple representations are natural kinds, or other privileged entities ([3]-[5]).

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Grounding Singular Thoughts in Object Files

*Maria Matuszkiewicz**

Recently a number of philosophers have attempted to ground singular thoughts in perception [3] by appealing to mechanisms such as *visual indexes* and *object files* postulated by vision scientists [4]. The project these philosophers pursue involves two tasks (i) an account of how these specific perceptual mechanisms enable thoughts about objects present in the visual field; (ii) an account of how the result can be generalized to non-perceptual singular thoughts.

Attempts to ground singular thoughts in object files face two kinds of objections. The more obvious one has to do with the generalization problem: granting that visual indexes enable us to have singular thoughts about objects present in the visual field, how can these mechanisms – specific to perception – account for singularity of non-perceptual thoughts? I will consider the solution to this problem proposed by Jeshion, pointing out why I take to be insufficient. The second objection questions the assumption that visual indexes can even account for singular demonstrative thoughts. Geirsson claims: "there is no evidence that we think of an object through a FINST object file, since the object file may contain no information beyond what is built into the causal processes of perception" [1]. I will examine this objection in detail, along with Geirsson's positive proposal to ground demonstrative thoughts in attention. I will argue that both the objection and the proposal stem from a particular conception of visual indexes and object files proposed by Pylyshyn [4]. According to this view visual indexes are pre-attentional and they refer via purely causal mechanism. However, some researchers have recently argued that this conception is wrong: that descriptions may play a role in fixing the reference of *visual indexes* [2], and that the multiple object tracking experiment shows that attaching visual indexes to objects involves attention [5][6]. Finally I will consider whether this revised version of visual indexes serves better the task of grounding demonstrative thoughts.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Retinal image quality of the human eye across the visual field

Kristof Meding, Michael Hirsch, Felix Wichmann*

When humans are watching scenes in the surrounding world, light rays propagate through the lens of the human eye onto the retina. This is the first stage of all visual processing. Despite the robust design of the lens, aberrations impair visual quality, especially in the periphery. Wavefront sensing is used to measure individual lens aberrations and to calculate point spread functions (PSFs) and retinal images on patches across the visual field. However, it is still unknown how optics impair image quality as a whole and no systematic analysis has been conducted up to now.

In this work, data from peripheral wavefront aberration sensing is used in combination with the Efficient-Filter-Flow algorithm to calculate retinal images for a wider visual field. We extended the work on monochromatic PSFs from Watson[1] with data from Polans et al.[2] to generate retinal images for a $50° \times 80°$ visual field. This is the first time that retinal images for a larger visual field are obtained from measured wavefront aberrations. These images show that the optical performance of the human lens is remarkably constant up to 25°. Additionally, an anisotropy in image quality between nasal and temporal side was found.

The dataset from Jaeken et al.[3] was used to check this anisotropy for more subjects. We quantified the optical quality by calculating PSFs and modulation transfer functions (MTFs). This second dataset verified the difference between the nasal and temporal side and additionally revealed differences in off-axis behavior of emmetropes and myopes.
Furthermore, we could identify the anisotropy between nasal and temporal side in a psychophysical experiment by measuring the visual acuity with two point sources.

We anticipate our results to be a starting point for the computation of retinal images for large visual fields. With aberration measurements for large visual fields, one could further investigate the claim that the optics of a human eye show a wide-angle-lens behavior as proposed by Navarro in 1993. Additionally, improved computing of retinal images could benefit vision models using these, e.g. early vision models or gaze prediction models.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Ideomotor simulation in manual action – Combining brain activity and eye-tracking measurements

Shirley Mey, Dirk Koester, Thomas Schack*

Communication between humans and computers is getting more and more relevant for all fields of our daily life. It is important to make this communication as intuitive and applicable as possible for all classes of population, independent of personal skills and abilities. Because human-computer interfaces are already involved in daily life actions it is necessary to find a method which is usable in everyday life and not only under laboratory conditions. Compared to existing FRP (fixation- related potentials) studies, we combined simultaneously recorded EEG with eye-tracking data to distinguish between task-relevant and irrelevant objects in a more natural environment.

The experiment was done in an electrically shielded room by the measure of a 64 electrode EEG system combined and synchronized with a remote eye-tracker. The task was presented on a computer screen in front of the participants.

The experiment consist of two conditions. A counting condition in which participants had to search for particular object classes, and an exploration condition in which the participants only had to explore the scene. The crowded scenes consist of at least two object categories with some similar features like shape or functionality, and additional background objects.

We predict a significant difference in the brain activity by observing task relevant and irrelevant objects. Because the attention should be focused on task relevant objects, especially a higher P300 for this objects is assumed.

Our experiments show that dependent on the fact an object is important for a given situation, the neurocognitive signature is different by observing relevant than irrelevant objects. Coming from a visible search task, the results show that for analysing FRPs, because of the novelty effect, it is enough to have one to three fixations on an object. The FRP component effects seem to decrease with every fixation on the same object. The FRPs are averaged potentials after each fixation onset on an object of task relevant or irrelevant object categories. A closer look to the affected brain areas shows that positive effects occur in frontal central regions by observing relevant objects. This, and also the time window of 350-700ms after fixation onset, is an indicator for a P300 component, and particular concerning the region, a P3a effect. The event-related potential component P3a is known as an indicator related to attention and processing novel stimuli. As summary it is shown that there is a higher cognitive effect by evaluating task relevant stimuli compared to non-relevant stimuli shown in a P3a. These findings can be used as basis for interaction designs for brain-computer interfaces (e.g. online classification algorithms).

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

The effects of music-based interventions on Parkinson disease

Zahra Moradi, Keyvan Yahya, Boris Kleber, Nelson Mauro Moldanato, Eckart Altenmüller*

Parkinson disease (PD) primarily known as a movement disorder, is also associated with impairments in emotion processing. Previous evidence demonstrated that music perception engages the brain regions essential for the planning and performance of movements. Music-based interventions could potentially improve both motor and emotional disturbances in PD patients [1].. We show that predictive models provide a neurobiologically plausible account for understanding the effects of music-based interventions on PD. Since music provides an anticipatory temporal template for acoustic sequences, the brain could use this template as a reference for mapping both motor and emotional responses [2]. Music-based interventions may thus help to improve the prior conjectures over time to reduce prediction errors in both motor and emotional responses in PD patients. We propose a biologically-inspired Bayesian model to account for melodic expectations in monophonic music (consisting of a single part without any accompaniment). This model is based on encoding the probabilities of perceived musical notes as the internal belief (prediction/expectation) with a number of generative models and incorporates Bayesian inference to the model in order to capture the continuous variations in dynamic musical expectation. Given optimal parameters, this model can predict the responses of the participants for the diverse ratings of the rhythms in potential experimental data. We propose a Bayesian model consisting of three major parts: input process, generative models and Bayesian inferences. The model compares the predictions of this generative model to the observed sensory input to infer the properties of the presented stimulus. Hence, a set of beliefs are generated by comparing between prediction and outcome. The internal beliefs represent the probability of the stimulus caused by sensory input. Whereby the Bayesian inference, the model will obtain the probability of gaining reward following the current internal belief encoded by the nervous system given the synchronized rhythmic stimulus. Using predictive models, we aim to explain the underlying mechanisms by which music can benefit Parkinson disease patients and suggest future studies to fill in the gap of our knowledge on beneficiary effects of music on PD. In sum, our study suggests that prediction error contributes to the problems of PD and temporally organized expectations of future acoustic events help the brain to synchronize the preparation of a motor response.

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Cognitive Neuroscience, Wednesday, Sep 5, 10:30-12:00

Common Ground with Dialogue Systems for Fault Diagnosis: How Should They Ask for Clarification?

Romy Müller, Dennis Paul*

Psycholinguistic research provides a wealth of theories to guide the design of human-machine interaction. For instance, when industrial fault diagnosis is supported by conversational case-based reasoning, it is essential for humans and dialogue systems to establish common ground [1]. As humans are imprecise in their wording and there is considerable interindividual variation in object naming, dialogue systems need to understand what concepts human utterances refer to. But how should dialogue systems react when having trouble in reference resolution? Inspiration can be drawn from research on conversational grounding [2]. The present study investigated how three conversational strategies applied by a dialogue system affect performance and verbal effort.

In a Wizard-of-Oz experiment, participants typed descriptions of faulty packages (e.g., broken yoghurt cups) into a dialogue system. Following this description, the dialogue system requested clarification in one of three ways: rephrasing the participant's utterance in common terms (CT), rephrasing it with the fault's technical term (TT), or asking participants for self-correction (SC). Subsequently, participants could either accept or reject the dialogue system's rephrasing in CT and TT, and insert a new description in SC. In the following turn, the dialogue system provided a CT rephrasing in all conditions (unless the previous rephrasing had already been accepted in CT and TT), which again participants could accept or reject. In 80% of the trials, the dialogue system's first CT or TT rephrasing was correct, while in 20% it was incorrect (catch-trials). We hypothesized initial CT to speed up performance and reduce errors in catch-trials, while the effects of TT should depend on participants' strategies: For participants who thoroughly seek and provide evidence for mutual understanding, we expected solution time costs, while for less thorough participants we expected errors in catch-trials. In SC, we expected accurate performance but much higher solution times.

The results revealed highest solution times in SC, while the difference between CT and TT missed significance. Moreover, CT resulted in the lowest number of rephrasings, followed by TT and SC. Contrary to our hypothesis, error rates in catch-trials were highest in CT. Thus, while CT resulted in fast and effortless performance, it came with a cost in terms of increased errors when a seemingly simple explanation provided by the dialogue system was incorrect. These findings emphasize that the design of dialogue systems should consider psycholinguistic principles of seeking and providing evidence to ensure mutual understanding.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Human judgements of size and depth show hallmarks of explaining away

Nils Neupärtl, Constantin A. Rothkopf*

Visual cues to depth are inherently ambiguous and uncertain. Classic research in vision science has demonstrated that human judgments of depth are closely predicted by Bayesian cue integration, which weights individual depth cues by their relative uncertainties to reach a more reliable estimate. While this weighting of cues is linear for the case of Gaussian variability, more complex interactions of cues will result in strongly non-linear cue weighting, therefore providing a stronger test of predictions of Bayesian computations.

One such scenario is perceptual explaining-away, in which an auxiliary cue helps disambiguating the influence of two causes of a sensory measurement. Here we investigate whether human subjects utilize a known texture as auxiliary cue to infer size and depth of a ball when only a relative size cue is given in a 2d display and when a relative size cue is given together with stereo disparity in a VR display. In our experiment subjects decided in a 2AFC task which of two spherical objects, shown either on a computer screen or an HMD, was closer. The objects differed in their textures to appear as soccer, tennis or golf balls. Used size ratios were adjusted to match realistic size ratios.

Further, we gathered eye tracking data in the 3d condition to investigate how decisions were related to looking times. Based on a probabilistic computational model in the Bayesian framework we inferred subjects' prior beliefs about size ratios. Our model takes uncertainty into account both for the perceived ratio and participants' prior belief and enables us to use the collected behavioral data to infer the shape of subjects' internal belief structure. The results show that human decisions in size judgments can be explained as perceptual explaining away, prior size ratios are quite accurate, and response probabilities scale linearly with looking times.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Cognitive penetrability of perceptual experience: how can the activation of higher cognitive states modify our perceptual experience?

*Albert Newen**

To what extent is our perceptual a product of our beliefs, desires and past experiences? Cognitive penetrability describes the influence of high-level cognitive factors on perceptual experience, and has become a hotly debated topic in philosophy of cognition. In the talk we want to develop a general theory of cognitive penetration of our perceptual experience including examples from visual, tactile and auditory experiences [1]. The talk is organized as follows. It starts with the philosophical debate whether cognitive penetration exists at all and shortly demonstrates the main arguments for cognitive penetration of our visual experience. In the second part, I will argue that this theoretical framework is also adequate to account for cognitive penetration in cases of auditory and tactile experiences. Concerning tactile experience, we can especially report original data of a study initiated by myself and just realized in collaboration with experimental experts at Ruhr-University Bochum (including M. Brüne, M. Markmann, M. Tegenthoff): We decided to use the standard experimental setting of two-point discrimination and combine it with an hypnotic suggestion. The two-point discrimination task tests at which distance of two mental needles softly but clearly touching your finger you start to feel only one touch instead of two. The working hypothesis is that only under a specific hypnotic suggestion with a semantic content, we can observe a modified borderline distance of feeling only one touch while the contrasting conditions of normal consciousness and hypnosis without suggestion have the same borderline. This predicted result is achieved in the first study with 16 participants. The third part of the talk is dedicated to outline a solution to the question how cognitive penetration can be realized in cognitive processing. This has consequences for our theory of higher-level cognitive processes. Focussing on concepts the activation of which can penetrate our experience, we have to give up the general idea that concepts are abstract symbols which are completely separable from typical perceptual processes. The most plausible way to account for cognitive penetration is to accept – in line with [2] – that an activation of a high-level concepts includes the activation of typical perceptual information. Then a modification of perceptual processing together with the activation of a concept is no longer a mystery. An empiricist theory of concepts according to which concepts are partially involving typically sensori-motor and/or perceptual experiences can at least be accepted for perception-based concepts like banana, ball, puppet (even if we do not accept it for abstract concepts like gen or atom) [3]. This modest empiricism is sufficient to develop a plausible theory of cognitive penetration of our perceptual experience by perception-based concepts.

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Philosophy of Cognition, Monday, Sep 3, 10:30-12:00

A Neural Engineering Framework Implementation of Conditional Reasoning

Robin Pröllochs, Julia Wertheim, Marco Ragni*

Introduction: Conditional reasoning is needed for thoughtful planning and prospective thinking. With conditional reasoning we can draw conclusions based on "if…then" statements. It has been shown that deriving a conclusion for conditional reasoning is a complicated process requiring a lot of working memory capacity. In this project, we introduce an implementation of three conditional reasoning tasks and the Wason Selection Task in the Neural Engineering Network to gain insights about the mechanisms of neural computation in the case of the conditional reasoning process.

Methods: For modelling the reasoning process, we implemented the tasks in the Neural Engineering Framework Nengo. The framework implements spiking neurons, which have neuron response properties matching relevant brain areas. This allows us to build large-scale biologically plausible brain models. Additionally, the framework provides a Semantic Pointer Architecture to represent and process higher-level symbolic information while using neural computation as a basis. The model receives premises as an input through the vision module. The major premises are then stored and a subsequent mental model is created. After the input from the minor premise is received, the process of finding a conclusion is initiated. The model proceeds by performing compare operations and using rules implemented in the basal ganglia. Finally, the conclusion is returned via motor response.

Results: The model was evaluated by comparing the motor output with behavioral data from psychological studies. The network solves modus ponens (MP) tasks with a correctness rate of 94%. For modus tollens (MT), we have seen a slightly lower performance of 82%. The Wason Selection Task was solved in 68% of the cases correctly. Within the behavioural studies, a performance of 93% in MP and 77% in MT tasks was observed. [1]. In the Wason Selection Task, the correctness was 4% for social contract tasks [2] and 72% for abstract tasks [3].

Conclusion: For the Wason Selection Task, there is a quite significant difference in the performance throughout literature and it appears that context significantly affects the results. A task with familiar content is more likely to be solved correct than an abstract one. [3]. Our model is not capable of distinguishing between context; therefore, the data is not comparable. However, in comparison with studies on conditional reasoning, our model achieves similar performance for MP and MT tasks.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Proposing a Story-Based Method to Cognitively Evaluate Qualitative Representations of Motion.

Juan Purcalla Arrufi, Alexandra Kirsch†*

Describing motion qualitatively is an ubiquitous asset, according to the variety of applications that take advantage of it. Indeed, qualitative motion description enhances the analysis of movements, such as pattern analysis of sport players' trajectories [3] or dancers' bodily movements [2]. It simplifies the implementation of navigation routines, notably in human-robot interaction [1, 4], not only because it provides meaningful motion categorisations, but, also, by enabling reasoning [5] and decision-making [6].

At the core of motion description are the qualitative representations of motion. For that reason, and, because their number is increasing, we feel the need for a tool to evaluate them from a cognitive perspective. The challenge, however, is that each qualitative representation of motion has been mostly constructed by using a particular approach and motion properties, for example, QTC [3], OPRA [6]. For this reason, it is difficult to find general methods to evaluate them—and even more so from a cognitive perspective—, i.e., to see which motion properties should be added or eliminated in a representation of motion.

We present a candidate tool for such evaluation: a story-based method [8] with the two-fold effect. It allows us to identify motion properties that would more meaningfully categorise motions, if we add them to the qualitative representation. It also exposes current motion properties in the qualitative representation, whose categorisation is cognitively inadequate, and, thus, we might drop them out.

Through this method, we can set the fineness degree of a representation of motion by progressively incorporating more properties to the original representation of motion, until such representation is fully extended—when we cannot create more categories that are meaningful in a story-based sense. In any case, the major advantage and novelty of the method, is that we can apply it to any representation of motion that classifies motion scenarios, i.e., situations defined by the instantaneous positions and velocities of the entities.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Towards Satisficing Mental Models for Behavior Understanding

Jan Pöppel, Stefan Kopp*

Theory of Mind is the cognitive ability to reason about the mental state of others. It allows us to infer not only others' intentions but also their (potentially false) beliefs about us or parts of our environment. Developing artificial systems with similar capabilities is of great interest both from a cognitive science perspective, as artificial models can be used to test hypotheses about this mentalizing capability of humans, as well as a human-machine-interaction perspective: Inferring a user's intention and beliefs without the need for explicit communication will improve ease of use and collaboration.

One popular framework for designing such artificial systems capable of reasoning about mental states is the Bayesian Theory of Mind [1], which has been successfully employed in a range of different scenarios by using specifically designed mental models. So far these scenarios have been of limited complexity as Bayesian inference becomes intractable quickly as the number of considered mental states increases. One currently faces two problems when trying to expand the framework to broader usecases: 1. Designing mental models applicable to a wide range of scenarios and 2. finding ways to quickly perform inferences in these mental models to allow for their use in real-time interaction systems.

In the present work, we are trying to find solutions to both of these problems: In previous work [2] we have shown that a system capable of switching between simple models, each corresponding to specific assumptions about another agent's mental states, can explain human navigation data efficiently. We are currently evaluating sampling approaches to achieve similar results using more complex and general models. Sampling discrete mental states for each of the considered belief states makes inference feasible again. The likelihood of the observed data given the sampled mental states allows us to decide whether to stick to the current sample or modify it, effectively employing a "Win stay, lose switch" strategy which has been found in human causal learning [3].

Building upon this sampling approach we are evaluating if the way the sample changes to fit the observed behavior allows us to infer previously unknown mental states in order to allow the system to adapt to changes in the scenario.

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Language and Communication, Wednesday, Sep 5, 15:30-17:00

How Event Probability Impacts Sentence Comprehension: Modeling N400 Amplitudes in Reversal Anomalies

Milena Rabovsky, James L. McClelland*

The N400 ERP component has aroused much interest because it is thought to provide an online measure of meaning processing in the brain. However, despite more than 1000 empirical studies using the N400 as a dependent variable, the component's functional basis is still actively debated. We show that the Sentence Gestalt (SG) model, a neural network model of sentence comprehension, provides a unified account capturing a wide range of findings [1]. The model treats the N400 as reflecting the stimulus-induced change in a probabilistic hidden layer activation state implicitly representing conditional probabilities of all aspects of meaning of the event described by a sentence.

Here, we focus on a novel simulation of a finding that has triggered considerable theoretical uncertainty in the N400 community, namely the small N400 effect observed for role-reversed sentences such as "The fox that on the poacher *hunted*..." (literal translation from Dutch; paraphrase: "The fox that hunted the poacher..."; [2]). N400 amplitudes are typically increased for semantic incongruities, such that the small N400 for reversal anomalies is seen as surprising. While some researchers take this finding to indicate that comprehenders experience a temporary "semantic illusion" (of e.g., the poacher hunting the fox), others suggest that it might be best explained by assuming that N400 amplitudes are not related to sentence meaning, but rather reflect the retrieval of word meaning, which would be facilitated in role-reversed sentences due to priming (from e.g., "fox" and "poacher" to "hunting").

Our model successfully captures the empirical N400 data in reversal anomalies showing that the small N400 effect is compatible with an account of N400 amplitudes as reflecting the update of a representation of sentence meaning. However, probing the model's internal representations suggests that the model does not experience a clear-cut "semantic illusion". Instead, the model's internal representations reflect uncertainty and inconclusiveness induced by the conflict between syntactic cues and event probabilities. Thus, the model suggests a new way of understanding the small N400 in reversal anomalies. More generally, it suggests that the initial automatic formation of a representation of sentence meaning during comprehension is not built by slotting the meanings of individual words into a syntactic structure, but is instead jointly constrained by syntactic cues and event probabilities, and may remain in a state of uncertainty in cases of cue conflict. Subsequent controlled processes, presumably reflected in P600 amplitudes, may be necessary to resolve this conflict between competing cues.

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Language and Communication, Wednesday, Sep 5, 15:30-17:00

A Machine Learning Approach for Syllogistic Reasoning

Nicolas Riesterer, Daniel Brand, Marco Ragni*

Cognitive modeling combines the development of a *cognitive theory* for psychological phenomena and a *data-driven approach* optimizing the explanatory performance of the computational cognitive models. The field of cognitive modeling aims to build new cognitive models in order to improve the current state of the art to better explain observations obtained from psychological experiments. Apart from the computational methods, however, the properties of psychological data itself plays an important role in the success of cognitive modeling. Especially when considering methods from computer science or artificial intelligence, behavioral data such as categorical responses can produce suboptimal results, because discrete responses are represented numerically. This can lead to problems when aggregating responses (e.g., calculating the mean).

To solve this problem, we used *one-hot-encoding*, which represents a categorical response by a vector that contains exactly one 1 identifying the category and 0 otherwise. This representation, however, results in a substantially increased dimensionality, which makes it hard to process and identify patterns. To study the problem of representation, we adapted an *autoencoder*, a model routinely applied in the field of machine learning that was first mentioned in [2], which is capable of automatically determining an optimized encoding for arbitrary datasets. In our work, we focus on syllogistic reasoning as a demonstrative domain due to the predominant usage of aggregated categorical data [1]. To train the model, we used a dataset of 139 participants, where each of them gave conclusions to all 64 syllogisms. The resulting autoencoder was able to achieve a compression rate of 13.71 reducing the one-hot-encoded data from 576 to 42 dimensions with a mean squared error of 0.0058.

The obtained representation can help methods that need a dense description of the data. Additionally, we can directly apply our model to a reconstruction task, where the goal is to impute missing answers for syllogisms of an individual participant. For 50% dropout (i.e., 32 randomly selected syllogistic problems) our model managed to achieve a precision of 48% which far exceeds the performance of current state-of-the-art cognitive models and even outperforms the use of the most frequent answer. This demonstrates that the model is able to find individual reasoning patterns and confirms that latent factors in the behavioral data can be exploited. Furthermore, it establishes a novel upper bound for model performance.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Determining the Influence of Dyadic Role Relationship on a Dyad's Pedestrian Wayfinding Performance

Vanessa Romanescu, Iva Barisic, Christoph Hölscher*

Wayfinding is a task people perform daily, the relevance of which increases steadily as urban areas grow ever more densely populated. This study takes an in-depth look at the role division within a dyad performing a pedestrian wayfinding task in a real-world setting. During wayfinding, dyads can navigate either collaboratively or in a leader and follower configuration. Based on research in the fields of spatial cognition, wayfinding and navigation a theoretical model of role distribution within a dyad predicting the optimal role distribution for a wayfinding task is introduced. The model considers the distribution of spatial abilities (measured using the SBSOD [2]) and motivation to lead (measured using the MTL [1]) between the members of a dyad.

In this study 23 dyads solved eight wayfinding tasks in and around Zurich Main Station wearing mobile eye-tracking glasses. The participants completed the SBSOD before receiving maps and instructions to reach their first destination. At each destination the dyads were met by an experimenter and given new instructions. Having completed five tasks in their naturally emerging role relationship, all dyads filled in the MTL questionnaire and received instructions for the assigned role relationship in the last three tasks. For each task one participant was either asked to lead while the other handed in their map or the dyad was asked to actively collaborate. The resulting eye-tracking data was rated for role relationship by two independent trained raters, based on definitions of the two types of roles provided.

The results indicate that neither a collaborative nor a leader-follower role distribution within dyads leads to improved performance in all dyads. Additionally, the study found that a specific role relationship within a dyad could not be enforced using only instruction, as dyads seem to fall back into their habitual navigation patterns. All dyads performed best in their natural role relationship. The data analysis showed only limited support for the presented model, the main reason being challenges in the manipulation. The main implication of the study is, that like in car navigation, dyads in pedestrian navigation tend to collaborate. Also, it seems dyads should be allowed to navigate in the role relationship which emerges naturally to ensure their optimal performance.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Structural landmark salience in wayfinding – A comparison of left- and right-hand traffic

Florian Röser, Kai Hamburger*

Landmarks play a pivotal role in human wayfinding [e.g. 1]. Their value is described by the so-called landmark salience, which is, in general, subdivided into visual/perceptual, cognitive/semantic, and structural salience [e.g. 2]. With respect to structural salience, we repeatedly demonstrated that for remembering routes as well as describing them to others, the position of a landmark *before the intersection and in the direction of the turn* is the ideal landmark position [cf. 3,4]. The position, together with the visual and semantic aspects of the object, make up for the overall appearance in its surrounding environment. Previous findings, however, were all based on German speaking samples and –more problematic– on people socialized and living in a right-hand traffic environment. Thus, an important question remains: Do people from a left-hand traffic environment –e.g., United Kingdom– show the same landmark position preferences? For this, we ran an online experiment in which we presented screenshots of cross-road intersections with four objects (coloured circles) at the four possible landmark positions (before and behind the intersection, in and opposite to the direction of turn). In addition to a German sample (n=226; 166 females, M = 24.57 years, SD = 5.68), 34 participants from the United Kingdom participated (12 females, M = 42.06 years, SD = 13.40). Surprisingly, and in contrast to the German sample, the position preference depended on the direction of turn. For a turn to the right, these participants more often preferred the position *before the intersection* and for a turn to the left the position *behind the intersection*, both located at the side of turn. Our study provides clear evidence that we also need to address "traffic side" –and maybe cultural differences– when investigating landmark-based wayfinding, and, more generally, when investigating perceptual and cognitive processes in spatial cognition. However, for follow-up studies the participants should be properly matched with respect to sample size and age. Then, the reasons for this interesting difference should be further addressed.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

On a Formalization of Cognitive Architectures

Kai Sauerwald, Marco Ragni*, Tanja Bock, Gabriele Kern-Isberner, Christoph Beierle*

Human cognition is based on cognitive processes that are realized on the specific modular structure of the human mind. In cognitive science, cognitive processes are simulated by cognitive models, and general cognitive assumptions like the working memory, modules, and their interconnections are realized in a cognitive architecture. Cognitive architectures are realized as software frameworks that provide the modeller a language to define her models. While the architectures realize the cognitive perspective, typically, a cognitive architecture is described and presented in a rather informal way, whereas a formalized semantics is only given operationally by an implemented system. There are many different cognitive architectures and most, if not all, architectures have grown bottom-up by incorporating modelling demands. Some problems of current cognitive architectures are identified by the community (for instance [1]) of cognitive architectures: the complexity and incomparability of models defined in different cognitive architectures.

In our research, we address the problem of formally reasoning about cognitive architectures by providing a language to specify the computational processes of cognitive architectures, thereby abstracting from respective implementation details. We start with transition systems and carefully refine the idea of transition systems to match the specific characteristics of cognitive architectures. The central aspect about this formalization is that the information about "how" the information is processed is hidden away and the formal description concentrates on the change of memory elements over the time; this frees the formalization from the specific details of architectures. As a result, the obtained framework allows to model key features of different cognitive architectures, in an elegant and abstract way, and precisely relate and compare their key features and to prove properties about them. The framework also provides a flexible mechanism to formalize various resource constraints and restrictions for modelling resource limits of human memory and cognition. The formulated notation of equivalence we present within this framework focusses on the input-output behaviour of models and allows us to present exemplary comparative propositions about features of ACT-R and SOAR. In summary, our framework provides a common ground for reasoning about the computational processes that are realized in different cognitive architectures and for comparing these concepts in a precise way.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

A selective neuronal representation of incentive salience in Pavlovian conditioning

Daniel J. Schad, Michael A. Rapp, Maria Garbusow, Miriam Sebold, Stephan Nebe, Nils B. Kroemer, Sören Kuitunen-Paul, Elisabeth Obst, Christian Sommer, Marcus Rothkirch, Nina Romanczuk-Seiferth, Hans-Ulrich Wittchen, Ulrich S. Zimmermann, Henrik Walter, Philipp Sterzer, Michael N. Smolka, Florian Schlagenhauf, Andreas Heinz, Peter Dayan, Quentin J.M. Huys*

Background: Individuals differ in what and how they learn from experience. One important distinction separates 'sign-trackers', who approach cues during Pavlovian conditioning, from 'goal-trackers', who approach goals. In animals, only sign-trackers rely on phasic dopaminergic prediction errors in the nucleus accumbens (NAc) for model-free learning [1]. Goal-tracking may instead entail a cognitive representation of the unconditioned stimulus (US) via model-based learning. While human sign- and goal-tracking have been studied using eye-tracking [2], their neural substrates have not yet been examined.

Methods: We investigated 129 human subjects using fMRI and measuring eye position and pupil dilation during Pavlovian conditioning. In each of 80 conditioning trials, one of five different audio-visual conditioned stimuli (CSs) were presented before the US (a monetary outcome of -2, -1, 0, +1, or +2 Euro) was presented at a different location on the screen. During the third and last second of CS presentation, win-predictive CSs were fixated more than loss-predictive CSs ($p <$ .001). We used this effect of true CS value to define sign- and goal-trackers. Subjects, where win-predictive CSs attracted gaze more than loss-predictive CSs were classified as sign-trackers (N=43); subjects, where win-predictive CSs attracted gaze away from the CS (and towards the US-location) more than loss-predictive CS were defined as goal-trackers (N=43).

Results: Both groups were equally successful at learning ($p > .1$). Sign-trackers showed stronger Pavlovian-instrumental-transfer than goal-trackers ($p < .05$). As expected, model-free reward prediction error explained NAc BOLD responses only in sign-trackers ($p < .05$). Goal-trackers conversely showed a stronger model-based state prediction error signal in intraparietal sulcus ($p < .05$). Pupil dilation covaried with CS value only in sign-trackers ($p < .01$), while it decreased with decreasing model-based uncertainty across learning only in goal-trackers ($p < .05$).

Conclusions: As in animals, only sign-trackers seem to rely on the dopaminergic prediction error signal to attribute incentive salience to the CS. Goal-trackers seem to perform model-based learning about US outcomes via state prediction errors. Noradrenergic arousal systems as measured through pupil dilation reflect these learning differences. Based on animal results showing sign-tracking is associated with addiction and impulsivity, similar learning differences may relate to impulse control and addictive disorders in humans.

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Cognitive Neuroscience, Wednesday, Sep 5, 10:30-12:00

Prototype-based Categorization of Lego® Bricks

*Jona Schröder, Alisa Volkert**

In our study with different algorithms for categorization participants have to find certain Lego® bricks in boxes of pre-organized Lego bricks. While existing approaches, e.g. in machine learning [1], rather focus on finding *one* appropriate solution, we are also looking for the second best solution. In the case of sorting items into entities limited in space it might be helpful to find an alternative solution that might also be accepted by a user. This is of special relevance if we are thinking of potential tidying household robots. Especially it would be extensive work to code each position of any *new* item. There might be ambiguous items as well, like espresso cups. Should they be placed next to the other cups or next to the moka pot? There is not always only one right solution [2]. Here, we assume that humans would accept both places each. We claim that prototype-based knowledge representation (ProKRep) [3, 4] incorporating flexible categorization can easily find alternative places that are intuitive for humans.

One of our algorithms simulates an averaged real human sorting behavior drawn from a preliminary study. Another algorithm uses ProKRep. It categorizes test bricks to the most similar prototypes of the Lego boxes. The similarities are calculated by an augmented distance measure [2] based on object features (e.g. geometrical attributes), while the box prototypes are the averaged features of all bricks inside that box. For comparison we generate random categorization.

The participants have to explore the pre-organized Lego boxes with its about 200 bricks. After a certain time of exploration, new bricks are sorted in by one of our algorithms. After each new brick has been sorted, the participants have to find that brick. We then measure the performance of the participants in finding those bricks by the number of investigated boxes and their overall searching time.

While we expect the best finding performance resulting from the human sorting, we interpret the other algorithms being more humanlike the closer their resulting performance is to the human one. The comparison to the random sorting scales our results.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Active Inference, Belief Propagation, and the Bethe Approximation

Sarah Schwöbel, Stefan Kiebel, Dimitrije Markovic*

When we pursue goals, we are in a complex interaction with our environment: We observe our environment, infer unobservable (hidden) states of the environment, plan forward, evaluate if anticipated outcomes match our goals, and choose an action accordingly, which in turn might influence the environment. Thus, studying goal-directed behavior using multi-trial goal-reaching tasks allows investigating several underlying cognitive processes. Computational modeling can serve to describe and better understand these processes.

One such model is active inference [1], which rests on the idea that probabilistic inference can be used to infer hidden states of the environment, future states and observations, and which action to choose. As inferring posterior beliefs can be an arbitrarily complex mathematical problem, here, inference is done using an approximated posterior distribution, which is optimized by minimizing the variational free energy. So far, only a first order approximation - the mean-field approximation - had been used, where the posterior considers hidden states and observations to be independent of each-other. However, in a real-world task, like navigating through a city, the hidden states, e.g. locations on the map, are not independent of each other, as the current location depends on the one previously visited. Neither are observations, e.g. observed buildings, independent from states, as it depends on the location which buildings are visible.

Using a simple toy paradigm, we show that this assumption of statistical independence can lead to draw-backs in the planning process, which may result in a failure to reach goals. Therefore, the applicability of mean-field active inference as a model of goal-directed decision making might be limited. To improve active inference and broaden its usability as a research tool, we derived an agent based on a second order approximation - the Bethe approximation [2]. Here, the posterior beliefs contain pairwise statistical dependencies, so that consecutive states can be represented as influencing each-other, as well as pairs of states and observations. This markedly improved the performance in goal-reaching behavior in our toy paradigm. Interestingly, minimizing the free energy under the Bethe approximation requires using the belief propagation algorithm [3], which is widely used in the machine learning community, and can be mapped to possible neural implementations.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Predicting the Fixation Density Over Time

Heiko H. Schütt, Lars O. M. Rothkegel, Hans A. Trukenbrod, Ralf Engbert, Felix A. Wichmann*

When modelling human eye movements, we usually separate bottom-up and top-down effects, i.e. whether some aspect of eye movement behaviour is caused by the stimulus or by some internal state of the observer like their tasks or intentions. We also separate the orthogonal dimension whether the features used to guide eye movements are low-level—like local contrast—or high-level—like object locations. Furthermore, humans display systematic tendencies in their eye movements like their preference for certain saccade lengths and directions.

To disentangle these factors, we analyse how well fixation densities are predicted over time by, first, low-level bottom-up saliency, including a saliency model based on our early spatial vision model [1], and, second, a recent deep neural network based saliency model including low- and high-level bottom-up saliency (DeepGaze II, [2]).

To manipulate top-down effects, we use two datasets: One corpus dataset in which 105 subjects looked at 90 images to memorize them and a search dataset in which 10 subjects searched for 6 different targets with varying spatial frequency and orientation content superimposed over 25 natural images 8 times each resulting in 480 searches per image.

Based on the corpus dataset we separate the exploration into three phases: An onset response with the first saccade, an initial exploration lasting around 10 fixations and a final equilibrium phase. First fixations are most predictable but follow a different density than later ones. During the initial exploration, fixations gradually become less predictable. Finally, the fixation density stops broadening and the final equilibrium phase is reached in which fixations are least focused but still favour the same areas as during the initial exploration.

All saliency models predict fixations best at the beginning and gradually get worse. The simple saliency model based on our early spatial vision model performs as well as classical saliency models. However, DeepGaze II performs substantially better by using high-level information throughout the whole trial. This advantage is present at the latest 200 ms after image onset. On the search dataset all saliency models perform badly after a small initial prediction success. Instead we observe that subjects adjust where they look to the target they search for.

Our observations confirm that bottom-up guidance of eye movements can be overwritten almost entirely by task effects in static natural scenes. Nonetheless our data support some early bottom-up guidance, which includes high-level features already for the first saccade.

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Cognitive Neuroscience, Wednesday, Sep 5, 10:30-12:00

Modulation of Choice Perseveration in Delay Discounting Decision Making

Ulrike Senftleben, Martin Schoemann, Stefan Scherbaum*

When choosing between a small but immediate and a large but delayed reward, people discount rewards by their delay. The outcomes of such decisions are well described by discounting functions. However, in order to understand such delay discounting behavior it is necessary to look beyond decision outcomes and open a window on the dynamics of the decision making process. Recently, we showed that a neural attractor model is able to capture dynamics of delay discounting decision making on the within- and inter-trial process dynamics and the resulting behavior quite accurately [1]. Here, we provide further validation for this attractor model. We focus on inter-trial dynamics in the form of choice perseveration. According to our model, activation for the chosen option declines slowly after a choice was made; when the next decision trial starts, residual activity from the previous decision may bias the system towards the previously chosen option, which in turn leads to choice perseveration. In the present study, we derive hypotheses of how choice perseveration can be modulated based on an attractor dynamics account of decision making. Specifically, based on model simulations we expect that, first, a longer time interval between trials decreases choice perseveration due to increased time for the residual activity to subside, and second, presenting options asynchronously (showing the previously non-chosen option first) decreases choice perseveration due to a counteracting bias against the previously chosen option. We test these predictions in three experiments based on a non-verbal delay discounting computer game [1,2]. In the computer game, participants control an avatar that they use to collect monetary rewards; in each trial, they have to choose between two rewards. We sequentially manipulate the subjective value of the reward options to capture choice perseveration, i.e., that people stick to their initial choice even when the other choice option becomes increasingly more attractive. Our results confirm that choice perseveration decreases with longer inter trial intervals and with longer stimulus onset asynchrony, as predicted by our attractor model. This further supports the notion that attractor dynamics are a valid and useful tool that capture the dynamics of decision making processes and allow new predictions.

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Judgment and Decision Making, Tuesday, Sep 4, 10:30-12:00

How The Appearance of Adversarial Avatars Affects Player Behavior in Computer Games

Nino Silveira, Rul Von Stülpnagel, Vincent Langenfeld*

The Proteus Effect describes people's tendency to adapt their behavior depending on the appearance of their virtual avatars [4, 3]. In contrast, the appearance of an adversarial avatar (i.e., an "enemy") on a person's behavior has been far less investigated. Related research found that sharply contoured objects might convey a sense of threat [1] and that participants felt safer around non-spiky as compared to spiky objects [2]. We tested the hypothesis that people playing a computer game avoid spikier in favour of rounder enemies, with the underlying assumption that spiky enemies are perceived as more hostile.

We generated and presented 32 abstract avatar designs with varying spikiness/roundness to 24 participants. All designs were rated on negative and positive semantic differentials (e.g. peaceful/aggressive) as well as their perceived roundness or spikiness. On 7-point scales, spiky shapes (M = 5.0) were perceived as more negative than round shapes (M = 3.2). A Pearson correlation between the semantic differentials safe/dangerous and round/spiky showed a positive correlation, $r(763) = 0.71$, $p < 0.001$.

Forty participants (28 males; M = 24.6years, SD = 6.2) took part in the main study resembling a first-person shooter game. Participants were to collect as many diamonds as possible. At twelve decision points, they had to choose to confront a round or a spiky enemy. These enemies were selected from the six most negative rated (i.e., spikier) and the six most positive rated (i.e., rounder) designs of the pre-study. The assignment to collect diamonds in the gameworld was implemented as a distractor, death and hits against the player were punished by partial loss of diamonds. There were no differences between round and spiky enemies' behavior. Across all participants and decisions, round enemies were chosen significantly more often than spiky enemies ($\chi^2 = 9.63$, df = 1, $p < 0.001$).

We conclude that computer players' behavior can be significantly affected by an enemy's design, which is in line with previous research [1, 2]. Our findings can be used in game development to enhance enjoyment and suspense by reversal of those expectations. We are currently working on a second study where participants play the game from a third person perspective, so that we can manipulate the player's avatar to be spiky or round, respectively.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Effects of structurally and visually salient landmarks on memory for turning directions

Benedikt Solf, Rebecca Albrecht, Rul von Stülpnagel*

Research on the effects of landmarks on human wayfinding has emphasized the role of visual and structural salience: A landmark's position at a crossroad has been found to affect its selection for future orientation. Participants tend to choose landmarks in turning direction more frequently than landmarks in the opposite direction. Additionally, participants prefer a visually distinctive over other landmarks. However, the effects of structurally salient landmarks on memory retrieval for a turning direction at crossroads remains less studied.

A first study was realized on a computer screen by presenting an abstract crossroad with four corners from the ego perspective, one of them the visually salient landmark. The corners in turning direction are structurally salient. The crucial distinction was made between convergent cases (i.e., visually and structurally salient landmark positions on the same side) and divergent cases (i.e., visually and structurally landmark salient positions on opposed sides). Participants repeatedly studied routes consisting of five crossroads, and were subsequently probed for the turning direction at a single crossroad. This paradigm prevented participants from remembering a fixed sequence of turns, thus enabling a memorization strategy unrelated to landmark saliences. In target trials, the probed crossroad resembled one of the studied crossroads. In foil trials, we also tested crossroads not being part of the learned route to prevent guessing as a strategy. Participants were to indicate that the presented crossroad was new to them.

Error rates for convergent targets were significantly lower than for divergent cases.

In a second study, we will extend our paradigm to require participants to process the presented crossroads from a survey perspective. Participants study crossroads in the same design as in Study 1. The probed crossroad is always a target, but can be presented from the viewpoint of all four possible directions. Participants are asked to indicate the turn leading in direction to either the destination or the start of the previously learned route. The variation of probed viewpoints and directions emphasizes the encoding of the crossroads independent of the studied (and thus a survey) perspective. We expect lower error rates at crossroads which are convergent in the learning phase as well as for crossroads tested in direction of the destination.

Our findings show that at least in a highly controlled VR setting, structurally salient landmarks are not only preferred in selection tasks, but can improve memory recall as well. However, care must be taken because conflicts between visually and structurally salient landmark positions may impair route recall. Future research needs to test the transferability of our experimental results to a more complex real world scenario.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Resolving ambiguity through simulation in a virtual environment

Christian Stegemann, Martin V. Butz*

We start from the hypothesis that understanding language relies on mapping utterances to event-respective, sensorimotor-grounded common sense knowledge, which allows conceptual simulations (see [1], [2]). Along these lines, we have advanced a computational cognitive model [4], targeting ”Winograd Schemas” (WSs; [3]). WSs are thought to be only solvable with the help of common sense knowledge. Our model learns event-predictive knowledge structures from sensorimotor experiences in a virtual environment (VE, https://github.com/CognitiveModeling/BrainControl). The enhanced architecture resolves WSs by activating matching event-predictive encodings, essentially conceptually imagining the situation described in a WS.

Investigating VE-specific WSs reduces the complexity of entities and interactions possible, while preserving the layout of WSs. Consider a 2D-world with the player-character on the left and an enemy on the right with direct collision being the only possible interaction. An example of an adjusted WS would be (1) ”if the player-character hits the enemy, it will lose health”. In the VE, the enemy disappears when hit from above, while it damages the player-character when colliding head-on. Note that this is common knowledge within the game world. The most plausible interpretation of (1) is that ”it” refers to the player-character. Our architecture resolves this reference by considering different events that can lead to the player-character hitting the enemy (i.e. colliding with it). These include the conceptual consideration of hitting the enemy from above and from the side. The learned event-predictive model allows to form predictions about the interaction consequences, including the destruction of the enemy and the reduction in the player-character's health, respectively. Seeing that a decrease in health only occurs in the latter case, the architecture will strongly prefer this sequence of simulated events. Thus, a situated event imagination and its progression through time is matched with sentences, allowing the semantic resolution of referent ambiguities. Semantics are encoded in an accessible, event-predictive schema rule format, avoiding black-box approaches. Current restrictions in the event-predictive format preclude deeper simulations and more complex referent ambiguity resolutions. Accordingly, in future work we will foster the development of more complex common sense knowledge for solving more challenging WSs.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Joint Actions with Artificial Agents

*Anna Strasser**

Since artificial agents become increasingly prevalent in human social life, it is important to develop a conceptual framework providing notions by which we can describe human-computer interactions in more detail. This paper focuses on the question under which circumstances artificial agents may count as social agents in a joint action.

However, standard conceptions in philosophy tend to characterize joint actions as if they were unique to sophisticated human beings [1]. Consequently, artificial agents are excluded and can only be described as mere tools in interactions. Assuming that it is well possible to experience artificial agents rather as partners and not just as tools, I suggest an expanded notion of joint action, that is applicable to artificial agents.

Current minimal approaches present a promising starting point for establishing a broader framework [2, 3, 4]. By questioning the necessity of certain conditions that come with the standard philosophical conceptions, such approaches can capture a wider range of socio-cognitive abilities. Following this rationale, I suggest that not all conditions we find with respect to human beings are necessary for acting jointly as such. Even though it is generally accepted that acting jointly requires at least "the ability to act" and "the ability to coordinate", the question of what specific conditions have to be met is still under debate.

By offering a minimal approach to agency and elaborating minimal conditions for the ability to coordinate with other agents, this paper suggests a minimal version of the standard notion of joint action. With respect to necessary conditions for coordination, I focus on three aspects of a required social competence:

1. Ability to anticipate behaviour of others and thereby gain an understanding of other agents (mindreading).
2. Proving a sensitivity to social cues by reciprocally exchanging social cues.
3. Ability to contribute to a minimal sense of commitment.

The specifications of minimally necessary conditions will provide a guideline to discuss whether certain human-computer interactions can qualify as minimal joint actions. In addition, the specifications of required abilities may contribute to the development of benchmarks for future roboticists' research.

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Philosophy of Cognition, Monday, Sep 3, 10:30-12:00

A neural dynamic process model for the autonomous generation of intentional states

Jan Tekülve, Gregor Schöner*

How do minds develop intentionality [2], that is, create inner states that are about the world (percepts, memories, beliefs: the mind-to-world direction of fit) or about how the world should change (actions, action plans, desires: the world-to-mind direction of fit). Cognitive Architectures, such as ACT-R or SOAR, account for intentionality by postulating that production rules generate abstract representations, whose linkage to sensory and motor systems is delegated to asynchronous modules [3].

How the different psychological modes of intentionality emerge from neural processes that are driven by sensory inputs and that ultimately drive actuators is not directly addressed in such work. Here we explore this question within the theoretical framework of Dynamic Field Theory (DFT) [1]. In DFT, the time-continuous evolution of activation in neural populations is driven by inputs, but also stabilized by neural interaction within and across populations. We postulate that intentional states of the different psychological modes emerge when instabilities drive activation from input-driven to interaction dominated regimes. Self-stabilized peaks of activation within neural populations determine the content of an intentional state while the state's psychological mode is determined by how the neural population is positioned within a neural dynamic architecture.

We illustrate the concepts in an architecture that controls a simulated robotic agent situated in a virtual environment containing colored cubes that can be "painted" with paint picked up from "color buckets". The agent can move toward targets or act on objects to dispense or pick up paint (intentions-in-action), can plan sequences of such actions (prior intention) and seek particular perceptual states (desires). The agent detects and classifies objects (perception), builds a scene representation (memory), and learns the contingencies of which paint transforms which color into which new color (beliefs).

In this minimalistic toy scenario, we are able to show how a set of neural dynamic mechanisms endows the neural architecture with the capacity to autonomously generate intentional states in the different psychological modes. Higher intentional states of the mind-to-world direction of fit (beliefs, memories) emerge from sequences of lower intentional states, while higher intentional states of the world-to-mind direction of fit (desires, prior-intentions) generate sequences of lower intentional states.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

“Why Should I Trust Interactive Learners?” — Explaining Interactive Queries of Classifiers to Users

*Stefano Teso, Kristian Kersting**

Trust lies at the foundation of major theories of interpersonal relationships in psychology [1]. Building expectations through interaction [2] and the ability of interpreting the other's beliefs and intentions [3] are necessary for (justifiably) establishing, maintaining, and revoking trust. Hoffman *et al.* [4] argue that interpersonal trust depends on the “perceived competence, benevolence (or malevolence), understandability, and directability—the degree to which the trustor can rapidly assert control or influence when something goes wrong,” and Chang *et al.* [2] advocate that trust is “dynamically updated based on experiences”.

Surprisingly, the link between interacting, explaining and building trust has been largely ignored by the machine learning literature. Existing machine learning explainers such as LIME [5] focus on the batch learning setting only, and do not consider interaction between the user and the learner, while interactive frameworks such as (co)active learning [6] do not consider the issue of trust. So, why should we trust interactive learners?

To fill this gap, we propose the novel framework of *explanatory interactive learning* [7]. In each step, the learner explains its interactive query to the user, and she responds by correcting the prediction and explanations, if necessary, to provide feedback. For instance, if the prediction is correct but the explanation is wrong, the user indicates the components that have been wrongly identified to be relevant in the explanation. Her feedback is used to produce automatically counter-examples, added to the training set to correct the explanation. We also present the model-agnostic method CAIPI, instantiating our framework for active learning. CAIPI learns interpretable models locally around queries of any active classifier using LIME for drawing explanations of the corresponding predictions. A user study as well as image and text classification experiments demonstrate that this can boost the explanatory power of and the trust into the learned model.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Cognitive Load of Planning: Scanpath Sequences as Indices for Turbulence in the Search Space

David A. Tobinski, Oliver Kraft*

Abstract. While problem solving competence (PSC) is discussed as one of the 21century core competences, planning is the heart of PSC. Planning and Problem Solving research uses the Tower of Hanoi (TOH) paradigm since its beginnings. The TOH can be classified as an interpolation problem, respective a planning task. A given initial state has to be transformed into a well-defined goal state using well-instructed operators. It is well discussed that all the important information, the cognitive load of planning (CLP), is flooding working memory (WM) capacity. Thus sub-goals have to bridge the gap between (WM) and long-term memory (LTM). A subgoaling strategy had been early discussed by Simon [1]. Identifying this kind of strategy with eye tracking is one of our objectives. A quasi-experimental eye tracking study has been conducted at the University of Duisburg-Essen with 31 participants. Therefor a digital version of the TOH (TOH-D) was programmed. A sub-sample of 13 participants solved not only the traditional three disks version (TOH-D3D), but also an information reduced two disks version (TOH-D2D). The fixation counts within three AOIs around the three stacks have been analysed and represent the current search space. The significant results of differences in the eye movement patterns can be interpreted as a strong hint for a very turbulent search space of the weak performer and a uniform planning strategy pattern of the well performer.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Enteric, mirroring and predictive self-consciousness

*Antonella Tramacere**

I offer an ontogenetic account of self-consciousness which includes the role of the enteric nervous system as a basic volitional self-organizing system, the mirror neuron system (MNS) as a neural circuit for perception of self and others' behavior, and the predictive coding as a computational framework to infer functions from cerebral connectivity.

Some attempts have been made to explain how minimal forms of self-consciousness (i.e., minimal self) develop through predictive coding processes: the organism tracks regularities in sensations and movements and forms multi-levels expectations of the own properties and activity, by minimizing the discrepancies between expected and actual signals in correspondent areas of the brain [1] [2].

According to these accounts, the minimal is implemented in distributed medio-frontal and temporo-parietal networks supporting goal-directed behavior. These networks are *not* considered *the* place of consciousness, rather as underpinning the planning and execution of goal-directed movements that are crucial in evoking the sense of ownership and agency that characterizes the experience of one's body as its own. These networks partly activates during the perception of others' behaviour (and are known as the MNS), emphasizing that the basic experiences we entertain of ourselves are from the very beginning driven by the interactions with others [3].

I will argue that, by attributing self-consciousness only to goal-directed actions (the one where agent takes expected action outcome in account), these descriptions fail to acknowledge that also young babies and other animals show self-conscious behaviors. I will thus propose to analyze and test how the emergence of self-consciousness builds on the modulation between enteric and mirroring phenomena, by considering evidences regarding facial behavior in human newborns [4].

This will be my "stage zero" of development to show that the minimal self is grounded on flexible volitional predispositions informed by enteric mechanisms and characterized by the reward-related properties of testing the expectation to be a volitional agent interacting with a volitional agent. I will conclude that, through predictive coding applied to the enteric and mirroring system, newborns construct comparative models of self and others as intentional agents, minimizing errors related to the volitional expectations at all levels of the cerebral hierarchy.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Vibrotactile Displays as Learning Devices

Felix Weber, Rosa Maria Puca*

Theories about learning, such as the Cognitive-Affective-Theory of Multimedia Learning, assume auditory and visual processing streams on the stages of sensory memory, working memory and long-term memory. Learning with visual and auditory representations simultaneously is beneficial for learning [1].

But what about the tactile sense? We can perceive and remember touch, so it may have effects on all stages of memory and may potentially improve learning. In two studies, we have vibrotactile displays in declarative memory tasks.

In the first study, in a within-subject-design (n=7), participants learned Mandarin vocabulary in a tactile and a nontactile condition for 30 days. In the tactile condition, the tone, a semantically relevant feature in mandarin, was encoded by a vibration of the feelSpace belt [2] with an arbitrary mapping (front=tone1, right=tone2, back=tone3, left=tone4). Our hypothesis was that after habituation to the unfamiliar vibration and sensitization to the information encoded tactually, the performance for the tactile condition would superceed the nontactile condition. The analysis with non-parametric methods did not support this hypothesis. Instead, the data revealed highly diverse patterns between the participants. Motivational issues may have played a role. The need for longer training times to learn a vibrotactile mapping and to train tactile memory systems for declarative memory tasks may also serve as explanation.

In the second study, in a between-subject-design (n=129) we used a natural vibrotactile mapping with the feelSpace-belt: Directions. In the learning phase, visual stimuli moving randomly to one of 8 directions were presented. In the retrieval phase, directions for visual stimuli had to be recalled. During training in the congruent tactile condition, a directional vibrotactile cue, in the incongruent tactile condition an incongruent vibrotactile cue and in a nontactile condition no vibrotactile cue was given. Twelve sets of 24 items each were tested. The hypotheses that (1) in the first half of the experiment participants the tactile conditions would have worse perfomance, due to habituation and sensitization and (2) in the second half of the experiment the performance in the congruent condition would superceed the other conditions, could not be shown. Again the need for longer times to train tactile memory systems is an explanation.

Our future research aims at longer training times and mappings that are more natural.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Examining the Effect of Induced Beliefs on Cognitive Offloading

Patrick Weis, Eva Wiese*

Recently, the hypothesis that the human cognitive system is tightly coupled to the external world has gained increased attention in the cognitive sciences. The resulting unit of analysis, a distributed cognitive system, encompasses internal brain-based and external environment-based resources. In such a system, using external resources to complement brain-based processing has been termed *cognitive offloading*. The interest in understanding cognitive offloading behavior is paralleled by advances in technology and interface design that render external computer-based resources increasingly powerful and abundant. In the present study, we used an adaptation of the mental rotation paradigm to explore under which conditions human problem solvers offload cognition into the environment and when they rely on internal resources. For that purpose, we manipulated two parameters, the actual reliability (AR) of an external resource that afforded rotation of a virtual object and what participants believed the reliability was (BR). AR ranged between 0.5 and 1.0, and BR was manipulated via instruction: a naïve group was told that the external resource might not work all the time; an unbiased belief group was told that the external resource will work "X * AR out of 10 times" and a biased belief group was told that the external resource will work "(X * AR) - 3 out of 10 times". For example, if AR was 0.7, the unbiased group was told that the knob would work seven while the biased group was told that it would work four out of ten times. We measured how frequently participants offloaded the rotation process onto the external resource and how useful they found the resource to be. Results indicated that participants were less likely to recruit the external resource when a) its reliability was low (versus high), and b) they believed that the reliability was low (versus high). Whether participants were correctly informed regarding the reliability of the external resource (unbiased group) or just told that it might sometimes not work (naïve group) did not differentially affect offloading frequency, indicating that participants' reliability assessments based on experience with the system were well calibrated. Downwardly biased beliefs regarding the resource's reliability (biased group), however, significantly reduced the offloading frequency (versus other belief groups), suggesting metacognitive influences on offloading behavior on top of influences due to performance optimization. Interestingly, explicit assessments of the external resource's usefulness were only affected by actual but not believed reliability, suggesting that beliefs alter cognitive offloading frequencies via implicit rather than explicit processes.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Strong Memory Traces Decrease Reliance on External Information

Patrick Weis, Eva Wiese*

For many cognitive tasks, parts of the internal brain-based processing can be outsourced to external environment-based processing, a process that has been termed *cognitive offloading*. Previous research suggests that humans are sensitive to the utility associated with internal and external processing modes, enabling them to dynamically switch between processing modes as to maximize the overall utility by maximizing speed [1] or reward [2]. For example, slow access to external information is an indicator of low external utility and thus decreases offloading frequency [1]. While empirical evidence strongly backs the impact of the external resource's utility on offloading frequency, evidence regarding the impact of the internal resource's utility is scarce and mostly correlational. In the present study, we thus manipulated an internal resource's utility in a learning block and then measured the learning's impact on offloading frequency in a choice block that afforded choosing between internal and external processing modes. Specifically, we altered the internal resource's utility by establishing weak or strong memory traces linking a cognitive task (an alphanumerical problem, e.g. "A + 2") to its solution (in this case "C"). Strong traces were created by frequent practice of the respective problem, leading to a faster recall of the solution than weak memory traces, thereby increasing the internal resource's utility for the respective problem. If humans are indeed sensitive to the utilities of their internal resources and act accordingly, high internal utility should encompass less external processing whereas the reverse should be true for low internal utility, which is what we mostly found. Problems for which a strong memory trace had been established were solved less frequently with help of the external resource than problems for which only a weak trace had been established. Our results are thus consistent with previous studies suggesting that humans are impartial about whether to use internal or external resources for cognitive processes as suggested in [1], ultimately preferring the resource with the higher utility. At least in simplistic lab environments, people seem to be canny offloaders, selectively recruiting external resources at least partly based on the efficiency of their internal ones, supporting the claim that the cognitive system is rational and adaptive [3].

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Modulating Spatial Reasoning Capability by Anodal Transcranial Direct Current Stimulation

Julia Wertheim, Lorenza S. Colzato, Marco Ragni*

Spatial reasoning is a capability necessary for navigation in space and therefore a crucial element in everyday life. There are insightful cognitive theories explaining the cognitive mechanisms on which spatial reasoning is based, such as mental model theory. The identification of the underlying neural activations are valuable contributions for informing cognitive theories and testing hypotheses. Neuroimaging studies consistently found activation in the right posterior parietal cortex (PPC) and the left dorsolateral prefrontal cortex (DLPFC) associated with spatial and relational reasoning. Despite the usefulness of these studies, the links between the areas' activation and the emerging cognitive mechanisms is purely correlational. This means that the assumption of causality is only based upon the synchrony of cerebral activity and cognitive mechanism. Therefore, it is valuable to strengthen this link by methods that aim at revealing different aspects of causality. We used transcranial direct current stimulation (tDCS) as an attempt to modulate spatial reasoning. Anodal tDCS is known to enhance cortical excitability. From this we expect an enhanced reasoning capability if these brain regions are necessary for spatial reasoning. Our hypothesis is that anodal tDCS enhances cortical excitability which implies an increase in correct responses when participants are stimulated over the right PPC and left DLPFC.

We tested 51 participants from Leiden University (Netherlands) who had to solve deductive and inductive reasoning problems about spatially arranged objects in the form of semantic premises, e.g., "The apple is to the right of the peach; The peach is to the right of the pineapple; The pineapple is to the left of the lemon; The lemon is to the left of the pear. Is the following positioning correct? Apple - Peach - Lemon – Pineapple - Pear". These tasks were solved after the application of either anodal tDCS over the right PPC, left DLPFC or a sham stimulation over either region with 1mA and a stimulation time of 20 minutes. An enhancement of performance in spatial reasoning tasks was achieved by anodal stimulation over the right PPC (Kruskal-Wallis H test, $H(2) = 7.54$, $p = .023$), as compared to sham (Wilcoxon rank sum test, $p = .044$) and anodal stimulation over the left DLPFC ($p = .036$).

We could confirm our initial hypothesis that tDCS enhances spatial reasoning. Though the neuroimaging literature reports activity in both regions, interestingly, we were only able to modulate performance when stimulating over the right PPC. This implies that tDCS is generally a suitable method for cross-validating neuroimaging results since it can support the finding of regions necessary for cognitive processes. Our experiment stresses the need for causal methods for cross-validation and reveals that anodal tDCS can be used as one of these methods for investigating higher cognition.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Extraction of Time Dependent Physical Rotation Strategies

Stefanie Wetzel, Sven Bertel*

We report on results of a study in which 32 university students solved mental and physical rotation tasks using the iPad app **Rotate It!**. Although good spatial abilities are an important factor for individual success in STEM (science, technology, engineering, and mathematics) domains, spatial ability training is usually not prominent in school curricula. Among the key spatial abilities is mental rotation. Recent research has shown that mental rotation ability can be improved through physical rotation training [2]. We focus on physical rotation for this contribution and present a new data-driven method of analysing students' problem-solving behaviour and of extracting physical rotation strategies.

The tasks in our study followed the classical mental rotation paradigm by Vandenberg & Kuse [1] where two 3D cube figures are placed side by side. Participants had to decide whether the figures show *same* or *different* objects. During the study, each participant solved 96 mental and 96 physical rotation tasks. In the physical condition, our app allowed participants to rotate the right-hand figure using an Arcball metaphor. We logged times, answers, and how figures were rotated over time for the physical condition.

For an extraction of students' physical rotation strategies, we employed a correlation-based approach in combination with density-based clustering to identify physical rotation trajectories with similar global shapes. Using this method, we extracted a set of distinct physical rotation strategies which differ in times per task, success rate, and in how much students rotated per task. We then used patterns of individual use of these strategies to identify groups of problem solvers. The groups differ in their overall physical rotation success as well as in their physical rotation behaviour. For example, students who show low success rates tend to rotate figures less than higher-success students.

The results of this analysis are of practical importance for a live assessment of physical rotation strategies, which can then be used for the development of adaptive, physical rotation training applications.

In a comparison with mental rotation performance, we found a high correlation between physical and mental rotation success, suggesting that the identified differences in individual physical rotation strategy use may well have corresponding differences in mental rotation. We argue that individual physical rotation performance may thus be utilized to draw novel conclusions about students' individual mental rotation skills.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Computing the valence of pleasure and pain

*Wanja Wiese**

In a recent paper, Peter Carruthers [1] provides an insightful representational analysis of the valence of conscious experiences. In his lucid analysis, Carruthers makes the following two background assumptions:

(1) Both *seeming goodness* and *seeming badness* “exist on a single continuum of *seeming value*” [1, p. 6].

(2) “Valence-processing appears to be underlain by a single (albeit multicomponent) neurobiological network”, the signals of which “provide an evaluative ‘common currency’ for use in affectively-based decision making” [1, p. 3].

I will argue that there are theoretical objections to (1), and empirical objections to (2). These objections are not knock-down arguments, but I will show that there is a theoretically attractive alternative to (1) that can make sense of empirical findings conflicting with (2). Crucially, since (on my reading) neither (1) nor (2) are essential to Carruthers’s account, incorporating my suggested alternative promises to yield a more coherent and empirically plausible version of his account. Instead of (1) and (2), I will argue for:

1. There is a lexicographically ordered hierarchy of subjective values. At each level of this hierarchy, there is a single continuum of seeming value.
2. There is no single neural network specifically associated with the processing of valences. Instead, distributed representations of value contribute to affectively-based decision making.

[1] Carruthers, P. (2017). Valence and value. *Philosophy and Phenomenological Research*. doi: 10.1111/phpr.12395

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Philosophy of Cognition, Monday, Sep 3, 10:30-12:00

Identifying Predictor Problems in the Cognitive Reflection Test

*Jin Woo Ahn and Marco Ragni**

The Cognitive Reflection Test (CRT, [3]) is a set of seven mathematical problems specifically designed to induce impulsive responses that are wrong but can be correctly solved by suppressing the intuition (often called 'Type 1' processes) and further reflecting on the problem ('Type 2' processes required for conscious and deliberate reflection of the problem [1]). In this study, we investigated the dependencies among the CRT problems based on the framework provided by the Knowledge Space Theory (KST). The core assumption of the theory is that an individual's correct or incorrect response to some problem in a domain may imply her response to some other problems; therefore, by analyzing the response patterns of a problem set, it is possible to construct a prerequisite structure, represented as a graph, that captures the dependencies of the problems (for a detailed mathematical formulation, see [2]).

Method. 61 participants were instructed to solve the CRT problems. The collected data is used to construct a prerequisite structure of the problems by running the inductive item tree analysis algorithm (IITA, available from the R package *DAKS*; [5]), which generates the prerequisite structure that is most consistent with a set of response patterns as the input. Further, the transition probabilities between each pair of problems and their prerequisites are computed in order to quantify the degree of relation between the problems.

Results. The generated prerequisite structure of the CRT problems generated via IITA indicates that there is a hierarchy of difficulties among the problems, and that most of the investigated transition probabilities lie between 0.5 and 0.65. The highest probability was observed between problem 4 and problem 5 (0.65), and the lowest between problem 6 and problem 5 (0.38). Overall, the results indicate a recognizable dependency between the problems. Further research is necessary to examine its implication on the factors that influence the cognitive ability.

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

On the Role of the Basal Ganglia Pathways in Incremental Perceptual Decision Making Task

Keyvan Yahya, Fred Hamker*

The emphasis of the present study is on investigating incremental decision making in the context of categorization task. Incremental decision making is an important type of perceptual decision making that enables humans to make wiser decisions on the basis of accumulative information obtained over time. Its quintessential underpinning mechanism is fairly simple; the brain begins to gather evidence and carries on accumulating the incoming information up to the point when enough information for making a proper decision is obtained. This type of decision making could be very useful when the brain needs to gain more sensory information in a longer course of time to make the best choice over a set of alternative options at both individual and social levels. To investigate the underlying neural substrate of incremental decision making, many experiments have been set up backed up by the prevalent neuroimaging techniques such as fMRI, single trial analysis [1]. The main findings of these experiments revealed that the integration of sensory evidence represented by sensory neurons to form the variables of decision can take place in a number of different areas such as prefrontal, medial and ventral premotor cortices. Furthermore, other regions such as medial temporal lobe, lateral Intraparietal and Frontal Eye Fields showed significant activities during the whole process of decision making. One of the essential cognitive processes that could be taken into account in light of the new insights about incremental decision making is the significant role of subcortical structures such as the Basal Ganglia in categorization which has also been confirmed in recent studies [2]. These facts motivated us to present a computational model that simulates a categorization task that ought to be performed in a series of sequential steps and demonstrates how the interplay of the BG pathway will decide over the accumulated information whether to reserve or left the inhibition to take an action. In the pursuit of our quest, we will present a model consisting of the PFC, the MTL, the BG nuclei including STN, GPe, GPi, SNc in addition to ITC, and PM. Two types of fishes are given to the model and the model has to reach a correct decision over the categories the presented inputs belong to. At each time step, the direct and indirect pathways constantly observe the accumulated information about the fish and together with the knowledge acquired by hyper-direct pathway decide as to whether the threshold has been passed to release the inhibition. We will then examine the performance of the model on the basis of a categorization task. Finally, the results including the categorized exemplars as well as the accuracy and success rates of the model will be discussed and compared to that of the similar models such as COVIC [3].

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Poster Sessions: Monday, Sep 3, 15:30-17:30 and Wednesday, Sep 5, 17:00-19:00

Deciphering Dynamic Decision Making Using Cognitive Modeling Including Subjective Assessment

*Ziying Zhang, Nele Russwinkel, Sabine Prezenski**

More breakthroughs in computer science, psychology, and cognitive science allow us to obtain new insights for developing artificial intelligence (AI) that understand and predict the behavior and decision-making process of humans. In real changing environments, decision-making consists of series of decisions, and these depend on the corresponding feedback. Cognitive modeling provides a method to understand and explain them in general. This work is a demonstration of how cognitive modeling allows to flexible simulate decision-making in dynamic environments for different individuals as well.

This work builds upon previous work on cognitive modeling of a dynamic decision-making task in category learning [1]. We conducted an empirical study of an improved version of this task. This task requires participants to categorize tones (consisting of different acoustic features) and find out a target category, by applying acoustic strategies and learning from feedback of each trial's judgment. In the new version, two swaps on the correct key representing target tones were set. Furthermore, subjective confidence assessment and retrospective reports were added to explore participants´ thought-processes. The data of 50 subjects was collected. A first model based on the cognitive architecture ACT-R was developed, following the previous approach [1]. It begins by trying out one-feature strategies (e.g. frequency) and then switching to two-feature strategies (e.g. frequency + volume) as a result of negative feedback. However, after analysing each individual's performance, a large variance among individuals was found. The first model which only considers acoustic feature strategies could not simulate individuals who considered the possibility of the changing the correct key in each trial. Thus, to account for actual flexibility in decision-making, an upgraded second model was developed. This second model considers the actual (motor) operation in the task - pressing the correct key for target tones. It contains two independent strategy learning factors: the acoustic strategy derived from the first model and the new knowledge about key assignment. To control this knowledge of keys, a metacognitive count threshold mechanism of continuous negative feedback is added. The second model provides a better fit to the data of those participants who stated that they prefer to consider multi-factors in the task, and a similar fit for the average empirical learning curves than the first model. What our study proves is that cognitive modeling approaches with ACT-R can be extended to account for different individual cases. The capacity for predicting decision-making in complex tasks and furthermore being adaptable to individual differences in such tasks is a great potential for applying such ACT-R modeling approaches to develop better AIs.

[1] Prezenski, S., Brechmann, A., Wolff, S., & Russwinkel, N. (2017). A cognitive modeling approach to strategy formation in dynamic decision making. *Frontiers in psychology,* 8, 1335.

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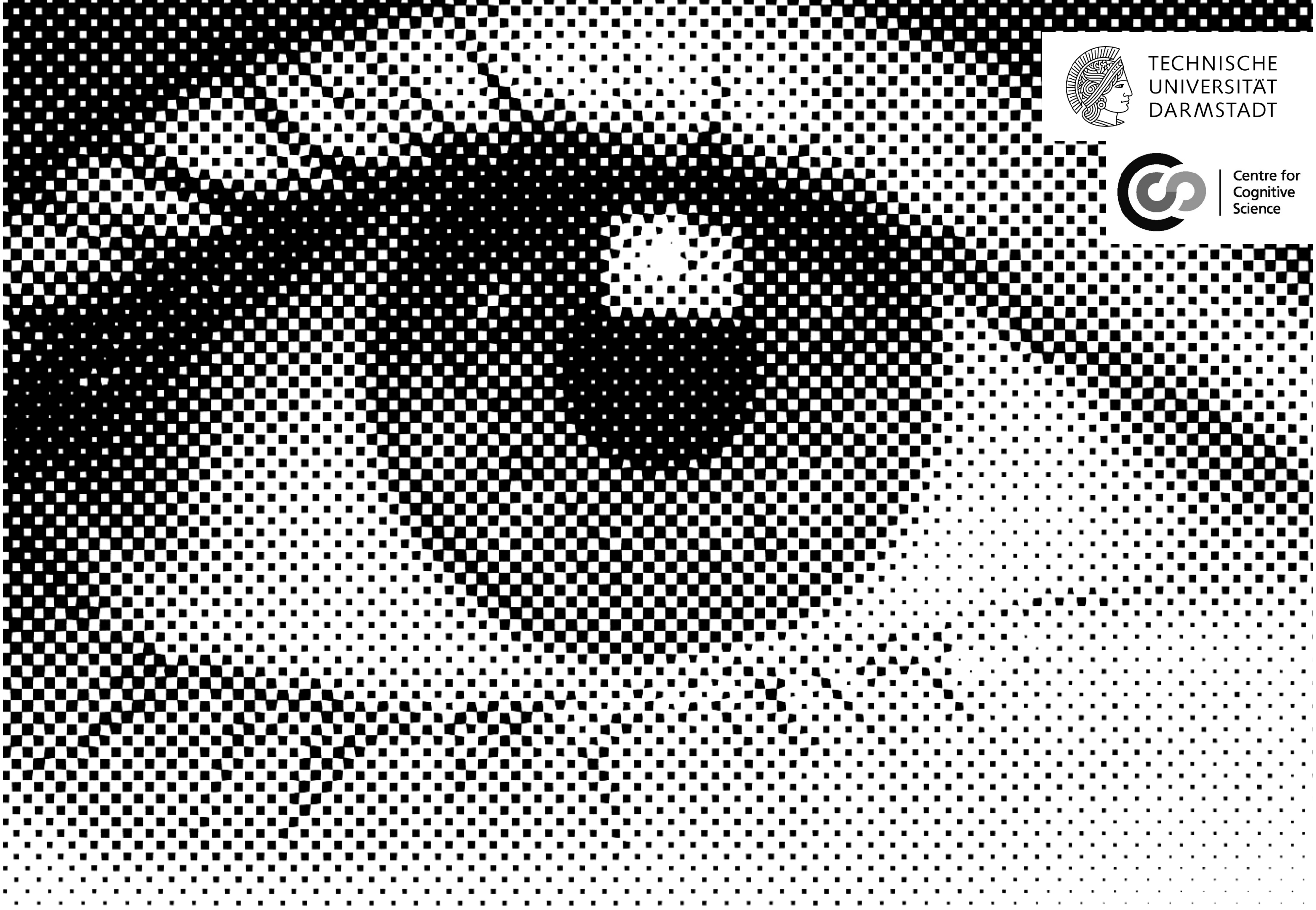

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