Universität Stuttgart
Cluster of Excellence EXC 2075 „Data-Integrated Simulation Science“

# SimTech Colloquium
# November 26, 2019

## Pfaffenwaldring 7
## Room: 2.157

SimTech

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**November 26, 2019**
**PWR 7, Room 2.157**
**8:30-9:10 am**

# Human Gaze Behaviour – Algorithms Dancing with Biology


Benjamin de Haas

Justus Liebig University Giessen, Germany


Human vision is highly selective. We can only resolve clearly what we look at directly, and typically make three eye movements per second. The quest to understand this process and predict human gaze behaviour has been a continuous back and forth between experimental psychology, computer vision and visual neuroscience. Here I will highlight three open questions in this ménage a trois: Why do some visual objects provoke stereotypical patterns of gaze? How does the visual system select high-level features for fixation? And what can we learn from individual differences in gaze behaviour? I will argue that the most promising approach to answering these questions is (continued) collaboration between disciplines.

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# Modeling Pavlovian Learning in Humans

Daniel Schad
University of Potsdam, Germany

Individuals differ in how they learn from experience. In Pavlovian conditioning models, where cues predict reinforcer delivery at a different goal location, some animals—called sign-trackers—come to approach the cue, whereas others, called goal-trackers, approach the goal. In sign-trackers, model-free phasic dopaminergic reward-prediction errors underlie learning, which renders stimuli ‘wanted’. Goal-trackers do not rely on dopamine for learning and are thought to use model-based learning. We demonstrate this double dissociation in 129 male humans using eye-tracking, pupillometry and functional magnetic resonance imaging informed by computational models of sign- and goal-tracking. We show that sign-trackers exhibit a neural reward prediction error signal that is not detectable in goal-trackers. Model-free value only guides gaze and pupil dilation in sign-trackers. Goal-trackers instead exhibit a stronger model-based neural state prediction error signal. This model-based construct determines gaze and pupil dilation more in goal-trackers.

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# Determinants of Tactile Localization


Stephanie Badde
New York University, USA



Sensing a tactile stimulus such as a mosquito on the skin and taking a look before swatting it feels effortless but requires considerable computations as each modality codes the mosquito’s location in a different reference frame. In the currently prevailing, topographic view, a tactile stimulus is automatically remapped into an external, world-centered reference frame before it is integrated with visual information about the same object. Our recent findings challenge this account at multiple stages of this computation. The perceived location of a touch sometimes differs considerably from its physical location: in some postures humans will occasionally perceive a touch to the hand as if it were on the other hand or on a foot. Such error patterns reveal that body features as well as canonical location of the touched limb guide tactile localization rather than the world location of the tactile stimulus. Moreover, we found the initial link between touch and vision to be weak unless attention is distributed across both modalities. In sum, tactile localization appears to be ill-characterized by topographic accounts and rather guided by internal variables such as knowledge about the body and attentional state.

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# Analysis of EEG Data in Naturalistic Experiments

Benedikt Ehinger
Radboud University, The Netherlands

Electrophysiological (EEG) research is increasingly moving away from simple controlled conditions towards complex, quasi-experiments and naturalistic situations that involve fast, multisensory stimulation and complex motor behavior. Examples are unrestricted eye movements while reading texts or watching movies, freely exploring a city with mobile EEG, or navigating and solving tasks in a virtual environment. In such naturalistic paradigms, the experimenter is not able to fully control the subject’s sensory input and actions. Consequently, such paradigms offer two main challenges for data analysis and interpretation:

1) Temporal overlap: If two events (e.g. fixations on a word) follow each other too quickly, the brain response of the response to the second event will overlap with the activity related to the first one. This is not unique to naturalistic paradigms but also true for traditional designs, e.g. the response to a stimulus can overlap with the response to a button press. This overlap (potentially of multiple co-occurring events) makes it difficult to assign unique activation to particular events.

2) (Non-)linear covariates: There are numerous uncontrollable variables in naturalistic paradigms, for instance, saccade amplitude, response time, fixation position, or local luminance. These variables might differ between the conditions of interest and therefore lead to spurious effects. In order to find the true underlying activity, we have to find a way to adjust for them.

In this talk, I will present an integrated statistical modeling framework, which allows us to analyze such challenging EEG data (unfoldtoolbox.org). I will introduce the problems described above and explain the advantages of our approach using simulations and data from several experiments. I will use combined EEG/Eye Tracking data as an exemplary case and further discuss potential applications in other domains.

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# From the Lab to the (Virtual) Wild: Model-based Assessment of Covert Visual Attention and Processing Speed


Jan Tünnermann
Philipps-Universität Marburg, Germany



Selective attention is a core process in human perception and cognition. Characterizing attention and stimulus processing is essential for optimizing interactions between humans and machines. However, typically, these aspects of perception and cognition are investigated in highly constrained laboratory settings with unnatural stimuli, such as simple shapes or letters, providing limited insights for more realistic scenarios. Here I present a new methodology which is based on modeling the task of binary temporal-order judgments with a deep and formal theory of visual attention. The task can be integrated into less constrained (up to now virtual) scenarios, such as games or driving simulations. The formal model is combined with hierarchical Bayesian parameter estimation, which enables assessing theoretically meaningful parameters of visual attention and stimulus encoding at the level of groups or individuals. It takes uncertainties into account and allows for performing simulations and predictions. The concepts at the core of this approach, which focuses on the visual domain, can be applied in other areas of selective information processing as well.

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# Domain General Principles of Efficient Human Exploration


Charley Wu
Harvard University, USA



How do people learn in real-world environments where the space of possible actions can be vast or even infinite? The study of human learning has made rapid progress in past decades, from discovering the neural substrate of reward prediction errors, to building AI capable of mastering the game of Go. Yet this line of research has primarily focused on learning through repeated interactions with the same stimuli. How are humans able to rapidly adapt to novel situations and learn from such sparse examples? I propose a theory of how generalization guides human learning, by making predictions about which unobserved options are most promising to explore. Inspired by Roger Shepard’s law of generalization, I show how a Bayesian function learning model provides a mechanism for generalizing limited experiences to a wide set of novel possibilities, based on the simple principle that similar actions produce similar outcomes. This model of generalization generates predictions about the expected reward and underlying uncertainty of unexplored options, where both are vital components in how people actively explore the world. This model allows us to explain developmental differences in the explorative behavior of children, and suggests a domain general principle of learning across spatial, conceptual, and structured environments.


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# Modeling Human Visiual Perception


Heiko Schütt
New York University, USA



Visual perception is the most important sense for humans and our primary path to understand the world surrounding us. Through well controlled experiments, vision scientists collected a vast amount of quantitative, reliable information on the human visual system. This empirical basis allows us to build detailed quantitative models of human visual perception, which are required to condense the data.
I will present two completed projects in which I contributed to such modeling:
In the first we modeled eye movements. Here, we found a way to calculate a likelihood for models with dependencies between fixations. I will illustrate the advantages of this approach and add some empirical findings on eye movement enabled by it.
In the second project we compared deep neural networks for object recognition to human observers. We find that deep neural networks are much less robust than human observers against distortions of the images, which sparked a general interest in improving deep neural network robustness.
Finally, I will talk about my current and future work. Currently, I work on grouping and perceptual organization. There I reconnect the handcrafted cognitive models we understand with the machine learning based models, which generalize to more natural conditions. In the future, I want to generalize this logic to other topics like early visual processing and hope to generalize well enough to apply my models to the real world.




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