Workshop: Pattern Recognition in Neuroimaging

Tuesday, 1st of September 2015
Center for Cognitive Neuroscience Berlin, **Freie Universität Berlin** (Seminarzentrum, Room L115)

Multivariate analysis of neuroimaging data has gained ground very rapidly in the community over the past few years, leading to impressive results in cognitive, affective, and clinical neurosciences. Pattern recognition and machine learning conferences regularly feature a neuroimaging workshop, while neuroscientific meetings dedicate sessions to new approaches to neural data analysis. Thus, a rich two-way flow has been established between disciplines. It is the goal of the workshop to facilitate exchange of ideas between scientific communities, with a particular interest in new approaches to the interpretation of neural data driven by new developments in pattern recognition and machine learning.

Confirmed Speakers:

John Dylan Haynes (*Bernstein Center for Computational Neuroscience Berlin*)
Dirk Ostwald (*Arbeitsbereich für Computational Cognitive Neuroscience)*
Johannes Stelzer (*MPI für Biologische Kybernetik in Tübingen*)
Douglas Garrett (*Max Planck Institute for Human Development*)
Stefan Bode (*Melbourne School of Psychological Sciences*)
Martin Hebart (*Institut für Systemische Neurowissenschaften)*
Kai Görgen (*Bernstein Center for Computational Neuroscience Berlin*)

Organizing Committee:
Carmen Morawetz

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Program

08.45-09.00	*Welcome*	
	Theoretical Background	
09.00-09.40	MVPA: Principles, pitfalls and perspectives	John-Dylan Haynes
09.40-10.10	An Introduction to Support Vector Machines	Dirk Ostwald
10.10-10.30	*Coffee break*	
10.30-11.10	Statistical inference and multiple testing correction in MVPA	Johannes Stelzer
11.10-11.50	Multivariate partial least squares (PLS) framework for neuroimaging	Douglas Garrett
11.50-12.30	The application of MVPA to event-related potentials	Stefan Bode
12.30-13.30	*Lunch Break*	
	Application	
13.30-14.10	Design of MVPA studies	Martin Hebart
14.10-14.50	Detect, Avoid & Eliminate Confounds in MVPA	Kai Görgen
14.50-15.10	*Coffee Break*	
15.10-15.40	The Decoding Toolbox	Martin Hebart & Kai Görgen
15.40-16.10	Decision Decoding Toolbox (DDTBOX)	Stefan Bode
16.10-16.30	*Coffee break*	
	Short Presentations: MVPA studies	
16.30-16.50	Time resolved decoding of working memory processes	Timo Schmidt
16.50-17.10	Neural representation of emotion regulation goals	Carmen Morawetz
17.10-17.30	Neural representation of bilingualism	Yulia Oganian

Abstracts

Theoretical Background

Prof. Dr. John-Dylan Haynes

Bernstein Center for Computational Neuroscience, Charité

09.00 – 09.40 **MVPA: Principles, pitfalls and perspectives**

Multivariate pattern classification has emerged as a useful tool in cognitive neuroimaging that allows to study content-based processing. This lecture will first give an overview of the basic principles, including the nature of patterned fMRI signals and discuss the choice of classifiers as well as spatial and temporal parameters. The second section will give an overview of methodological and conceptual pitfalls and caveats in the design and interpretation of MVPA studies.

Haynes, JD (2015). A primer on pattern-based approaches to fMRI: principles, pitfalls, and perspectives. *Neuron 87*, 257-270.

Prof. Dr. Dirk Ostwald

Computational Cognitive Neuroscience, Freie Universität Berlin

09.40 – 10.10 **An Introduction to Support Vector Machines**

Support Vector Machines (SVMs) remain to be employed in MVPA due to their rise to popularity in machine learning in the late 1990s. Technically, SVMs correspond to algorithmic solutions to quadratic programming problems with linear inequality constraints. The aim of this talk is to review the technical details of SVMs and to illustrate that SVM-based cross-validation MVPA is a somewhat indirect technique to measure the stimulus- or task-specific information content of an fMRI region-of-interest.

Dr. Johannes Stelzer

MPI für Biologische Kybernetik, Tübingen

10.30 – 11.10 **Statistical inference and multiple testing correction in MVPA**

In my talk I will present a solution for the multiple comparisons problem for classification-based MRI. The approach is based on nonparametric resampling methods, in particular permutation testing and Monte Carlo resampling. I will demonstrate why the commonly employed approach of t-based stats & gaussian random fields may fail in the context of classification both on theoretical but also practical grounds. In comparison to the t-based solution, the nonparametric approach discussed here features an increased spatial specificity and a lower rate of false positivity & negativity.

Stelzer J, Chen Y, Turner R (2013). Statistical inference and multiple testing correction in classification-based multi-voxel pattern analysis (MVPA): random permutations and cluster size control. *Neuroimage*. 65:69-82.

Dr. Stefan Bode

Melbourne School of Psychological Sciences, The University of Melbourne

11.50 – 12.30 **The application of MVPA to event-related potentials**

In recent years, neuroimaging research in cognitive neuroscience has increasingly used multivariate pattern analyses (MVPA) to investigate higher cognitive functions. These techniques are most commonly applied to functional magnetic resonance imaging (fMRI), however can also be implemented for spatial and temporal patterns of event-related potentials (ERPs), as measured using electroencephalography (EEG). This talk will illustrate the application of MVPA to ERPs, and the benefits of this approach will be discussed using examples from decision-making research. The applied component of this workshop will introduce a custom-made toolbox for MATLAB (the Decision Decoding Toolbox – DDTBOX) for multivariate analysis of ERPs, and its applicability and functionality and will be demonstrated.

Predicting errors from patterns of event-related potentials preceding an overt response (2014). Bode S, Stahl J. *Biological Psychology 103*, 357-369.

Dr. Martin Hebart

Department of Systems Neuroscience, Universitätsklinikum Hamburg-Eppendorf

13.30 – 14.10 **Design of MVPA studies**

How do I need to adjust my experimental design to be able to use multivariate pattern analysis? This is a question commonly asked by experimenters who are in the process of learning to use this analysis approach. In this talk I will approach that question by providing the audience with a number of experimental design and analysis choices that can help experimenters improve their signal of interest and which can simplify the overall analysis stream. In the following, I will mention common, but quite basic design confounds and simple approaches to prevent them. In this process, I will also touch on previously unrecognized more complex phenomena that are based on the choice of the design which can allow classification in the absence of any signal. Finally, I will bring these design choices into the context of the individual desired analysis level, be it a whole brain, region-of-interest, or searchlight analysis. Taken together, adjusting the design for multivariate analyses can in some cases prevent results from being uninterpretable, and in many cases can lead to improved sensitivity in detecting the presence of informative brain patterns.

Dr. Kai Görgen

Bernstein Center for Computational Neuroscience, Charité

14.10 – 15.50 **Detect, Avoid & Eliminate Confounds in MVPA**

Classical design principles (e.g. randomization) and control analyses (e.g. on behavioural errors, reaction time, age) are routinely applied in neuroimaging studies. However, it has not been tested whether this is still valid for studies using new analysis methods such as cross-validation or decoding that are both routinely employed in multivariate pattern analysis (MVPA).

In this talk I show that – counterintuitively – this standard practice can lead to the exact opposite of what it should achieve: Classical design principles can induce confounds instead of controlling them, and standard control analyses can give a false sense of certainty that a confound has been successfully controlled, even if it has not. These "Design-Analyses-Interactions" can cause systematic positive or negative biases (such as significant below-chance decoding accuracies), potentially yielding false positive or – equally problematic – false negative findings. Interestingly, many of these problems do not depend on whether multivariate or univariate analyses techniques are used, but instead are caused by designs that are not suitable for cross-validation, incorrect statistics, or false interpretations of decoding results.

I will illustrate the problem on practical examples, based on which I will motivate a simple remedy that serves to detect, avoid, and eliminate a large class of potential confounds. These best practices can - and should - be employed before, during, and/or after data collection. They include performing matching statistical analyses on (i) imaging data, (ii) design variables, and (iii) control data. Although our main demonstration is for neuroimaging experiments, similar arguments apply to other fields such as machine learning or genetics.

Finally, there's another great plus of this approach: It simply saves time! First, setting up analyses during design creation is much faster and easier than at a later stage (e.g. because variable names are still fresh in mind). And second, running these analyses occasionally ensures that the all design goals are indeed achieved (similar to Unit Testing in modern programming paradigms). Thus, this "Same Analysis Approach" does not only help to produce better science by detecting, avoiding, and eliminating confounds; it also saves time, money, and frustration.

Applications

15.10 – 15.40 **The Decoding Toolbox (Kai Görgen & Martin Hebart)**

The Decoding Toolbox (TDT) is an easy to use, fast and versatile Matlab toolbox for the multivariate analysis of functional and structural MRI data. It contains searchlight, region-of-interest, and whole-brain analyses, as well as many feature selection and parameter selection methods including recursive feature elimination. The toolbox is optimized for the use with SPM and can be used with minimal or no programming experience.
A simple decoding analysis can be conducted in just one line of code or with a simple graphical user interface. At the same time, for advanced users it is very easy to add new features and exploit the full functionality of the toolbox. In contrast to many other toolboxes, we have spent a lot of time on optimizing the error management, i.e. you get informative feedback and not some cryptic error message if you do something wrong.
In this talk I will give a brief introductory overview of TDT, with a focus on the interface to SPM and the intuitive error-correction features which both make decoding very simple for novices and advanced users alike. I will also demonstrate the functionalities of TDT in action.

Martin N Hebart*, Kai Görgen* and John-Dylan Haynes (2015). The Decoding Toolbox (TDT): A versatile software package for multivariate analyses of functional imaging data. *Front. Neuroinform.* 8:88.

https://sites.google.com/site/tdtdecodingtoolbox/

15.40 – 16.10 **The Decision Decoding Toolbox (Stefan Bode)**

For details please contact:

Stefan Bode

sbode@unimelb.edu.au

Short Presentations: MVPA studies

Timo Schmidt

Neurocomputation Neuroimaging Unit, Freie Universität Berlin

16.30 – 16.50 **Time resolved decoding of tactile working memory processes**

A central aim in working memory (WM) research is to identify brain regions that retain WM content. In this talk I will present an approach to study the temporal development of decoding accuracies across WM delays (Christophel et al. 2012). We tested the temporal unfolding of information representation in two tactile WM tasks. Subjects either memorized primarily sensory (the spatial layout of a pattern) or rather abstract (vibration frequency) features of tactile stimuli. We report novel evidence for content-specific processing in the right lateral prefrontal cortex when abstract stimulus properties (frequencies) are remembered.

Dr. Carmen Morawetz

Department of Biological Psychology and Cognitive Neuroscience, Freie Universität Berlin

16.50 – 17.10 **Neural representation of emotion regulation goals**

The use of top-down cognitive control mechanisms to regulate emotional responses as circumstances change is critical for mental and physical health. Several theoretical models of emotion regulation have been postulated; it remains unclear, however, in which brain regions emotion regulation goals (e.g., the down regulation of fear) are represented. Here, we examined the neural mechanisms of regulating emotion using fMRI and identified brain regions representing reappraisal goals. Using a multi-methodological analysis approach, combining standard activation-based and pattern-information analyses, we identified a distributed network of lateral frontal, temporal and parietal regions implicated in reappraisal and within it, a core system that represents reappraisal goals in an abstract, stimulus-independent fashion. Within this core system, the neural pattern-separability in a subset of regions including the left inferior frontal gyrus, middle temporal gyrus and inferior parietal lobe was related to the success in emotion regulation. Those brain regions might link the prefrontal control regions with the subcortical affective regions. Given the strong association of this subsystem with inner speech functions and semantic memory, we conclude that those cognitive mechanisms may be used for orchestrating emotion regulation.

Yulia Oganian

Department of Biological Psychology and Cognitive Neuroscience, Freie Universität Berlin

17.10 – 17.30 **Activation patterns reflect language identity decisions in bilinguals**

A crucial aspect of bilingual communication is the ability to identify the language of an input. Yet, the neural and cognitive basis of this ability is largely unknown. Moreover, it cannot be easily incorporated into neuronal models of bilingualism, which posit that bilinguals rely on the same neural substrates for both languages and concurrently activate them even in monolingual settings. We hypothesized that bilinguals can employ language-specific sublexical (bigram frequency) and lexical (orthographic neighborhood size) statistics for language recognition. Moreover, we investigated the neural networks representing language-specific statistics and hypothesized that language identity is encoded in distributed activation patterns within these networks. To this end, German-English bilinguals made speeded language decisions on visually presented pseudo-words during fMRI. I will discuss how multivariate pattern analyses compliment univariate approaches in investigating the neural code underlying visual word processing and language decisions in first and second languages.

Walk to workshop from Dahlem Dorf U-Bahn stop

The workshop is located in the **Seminarzentrum**, room **L115**. The Seminarzentrum is located across the Mensa. Below you will see walking directions from Dahlem Dorf U3 u-bahn stop. When you get off the U3 train, take the elevator at the end of the platform up to street level.