Statistical Analysis of Neuroeconomic Data

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Motivation

- Which **part of our brain** is activated during **risk related decisions** ?
- Can we provide **integrated dynamic analysis** to detect this area?
- Is there a **significant reaction** to specific stimuli in the hemodynamic response?
- Can we **classify** the risk attitudes of probands without using probands' answers?

fMRI Experiment

Experiement participants

- 19 volunteers (18–35 years, 11 females)
- no history of neurological or psychiatric diseases
- flat payment (10 EUR) +/- outcome resulting from a randomly chosen participant's decision

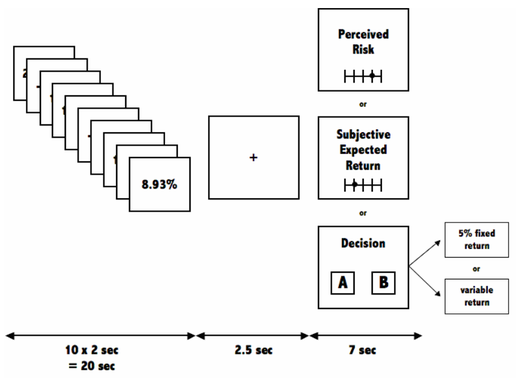
Risk Perception and Investment Decision (RPID) Task

Each trial of the RPID task consisted of two phases

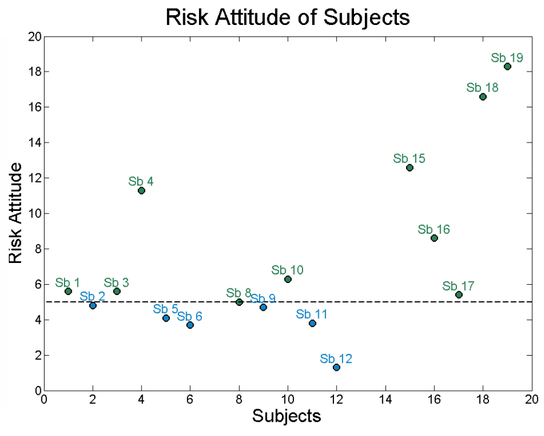
1. presentation of a *return stream*
2. decision between fixed and variable return or subjective judgment task of *perceived risk* and *expected return*

Risk attitude was estimated for each subject using his decisions and responses.

Risk Perception and Investment Decision Task



1. Returns Pause 2. Decision



Data

Series of T=1360 images, observed every 2.5 seconds, with J = 91 x 109 x 91 voxels.

➡ **High dimensional, high frequency, large data set!**

Fitting Data for the Model

- data points inside the brain included only
- first part of the experiment only ($T=722$)
- voxel´s index (i_1, i_2, i_3) as covariate X_j
- BOLD signal as response variable $Y_{t,j}$

Panel Dynamic Semiparametric Factor Model (Panel DSFM)

Estimation procedure in 2 steps:

1. Take the average of $\overline{Y}_{t,j}$ across all subjects *i* and estimate the common basis function in space, denoted as $\hat{\overline{m}}_l(X_{t,j})$ using:

$$\overline{Y}_{t,j} = \overline{m}_0(X_{t,j}) + \sum_{l=1}^{L} \overline{Z}_{t,l}\overline{m}_l(X_{t,j}) + \varepsilon_{t,j} \qquad 1 \le j \le J \qquad \text{(DSFM)}$$

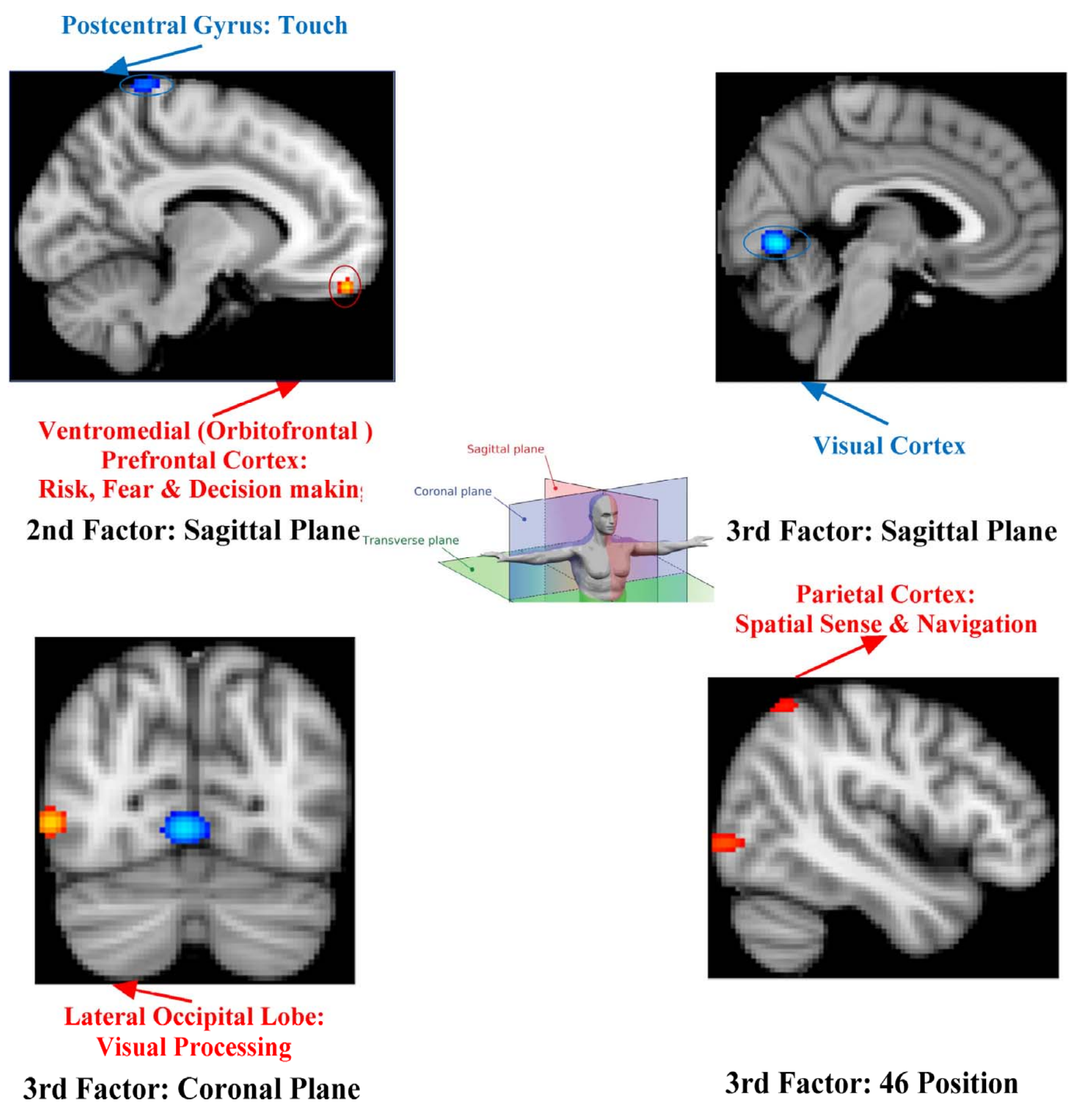
2. Given the common $\overline{m}_l(X_{t,j})$ for all subject *i*, estimate the subject-specific factors in time $Z^i_{t,l}$ by the ordinary least square method:

$$Y^i_{t,j} = \overline{m}_0(X_{t,j}) + \sum_{l=1}^{L} Z^i_{t,l}\overline{m}_l(X_{t,j}) + \varepsilon^i_{t,j} \qquad \text{(LS)}$$

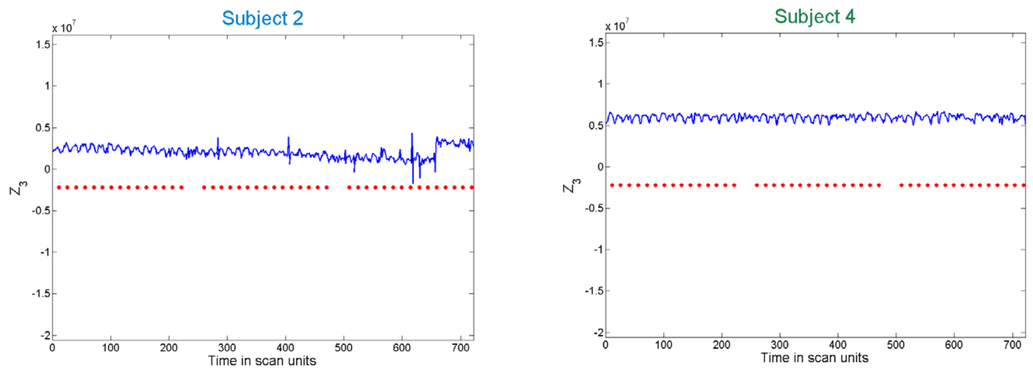
The optimal number of factors *L* is chosen by maximizing the explained variation.

Results

Selected factor loadings



Time-dependent factors for selected subjects



SVM Classification analysis

Observation: weakly (strongly) risk-averse individuals have smaller (larger) volatilities of $Z^i_{t,l}$ inside each trial

➡ SVM based on volatilities of $Z^i_{t,3}$

Classification rates:

		Estimated	
		Strongly	Weakly
Data	Strongly	0.90	0.11
	Weakly	0.67	0.33

Summary

- basis functions **identify activated areas**, neurological reasonable
- **volatility** of estimated factors show differences for subjects with different risk attitudes (Sb 2 vs. 4)
- SVM classification analysis of volatility in $Z^i_{t,3}$ can **distinguish weakly and strongly risk-averse individuals**

References:

Myšičková, A., Mohr, P.N.C., Song S., Heekeren, H.R., Härdle, W.K., (2010). Risk Patterns and Correlated Brain Activities. *Working paper*.

Park, B. U., Mammen, E., Wolfgang, H., Borak, S., (2009). Time series modelling with semiparametric factor dynamics. *Journal of the American Statistical Association*, 104 (485), 284-298.

P. N. C. Mohr, G. Biele, L. K. Krugel, S.-C. Li, H. R. Heekeren, (2010). Neural foundations of risk-return trade-off in investment decisions. *NeuroImage*, 49 (3), 2556-2563.