# Block-wise permutation tests for correlated multivariate imaging data

**Daniela Adolf and Siegfried Kropf**

*Department of Biometrics and Medical Informatics,*
*Otto-von-Guericke University Magdeburg, Germany,*
*email: daniela.adolf@med.ovgu.de, siegfried.kropf@med.ovgu.de*

**Keywords**: block-wise permutation, correlated sample elements, separated multivariate GLM.

In view of functional magnetic resonance imaging data, that is high-dimensional and correlated in time and space, we consider a multivariate general linear model (GLM) for a fMRI session with one person

$$\boldsymbol{Y} = \boldsymbol{X}\mathbf{B} + \mathbf{E}, \quad \mathbf{E} \sim N_{n\times p}(\mathbf{0}, \boldsymbol{P} \otimes \boldsymbol{\Sigma})$$

The data matrix $\boldsymbol{Y}$ contains $n$ measurements (successive fMRI scans) over $p$ variables whereas $p \gg n$. In general the null hypothesis is $\mathrm{H}_0 : \boldsymbol{C}'\mathbf{B} = \mathbf{0}$ with $\boldsymbol{C}$ being an $s \times m$-dimensional contrast weight matrix. Here contrary to the classical multivariate GLM, the sample vectors are correlated and $\boldsymbol{P}$ is supposed to be a first-order autoregressive process. To analyze these data non-parametrically, we use a block-wise permutation method including a random shift in order to count for the temporal correlation.

Furthermore, we want to be able to test any null hypothesis on the parameter estimates via this special permutation method. This is important because analyzing functional imaging data is particularly based on testing differences of parameter estimates. Therefore, we use a separated multivariate GLM

$$\boldsymbol{Y} = (\boldsymbol{X}_1 \boldsymbol{X}_2)\begin{pmatrix}\mathbf{B}_1\\ \mathbf{B}_2\end{pmatrix} + \mathbf{E} = \boldsymbol{X}_1\mathbf{B}_1 + \boldsymbol{X}_2\mathbf{B}_2 + \mathbf{E}$$

and the special null hypothesis $\mathrm{H}_0 : \mathbf{B}_2 = \mathbf{0}$ that is only related to $\boldsymbol{X}_2$, that part of the design matrix that contains the information of interest.

We will show that any null hypothesis on the classical multivariate linear model can be transformed into the separated model and can be tested via the block-wise permutation method including a random shift.

## References

[1] Friston, K.J., Ashburner, J.T., Kiebel, S., Nichols, T.E., Penny, W.D. (2007). *Statistical Parametric Mapping – The Analysis of Functional Brain Images.* Academic Press, Amsterdam.

[2] Kherad-Pajouh, S., Renaud, O. (2010). An exact permutation method for testing any effect in balanced and unbalanced fixed effect ANOVA. *Computational Statistics and Data Analysis* **54**, 1881–1893.

[3] Läuter, J., Glimm, E., Kropf, S. (1998). Multivariate tests based on left-spherically distributed linear scores. *Annals of Statistics* **26**, 1972–1988.

[4] Pesarin, F., Salmaso, L. (2010). *Permutation Tests for Complex Data: Theory, Applications and Software.* John Wiley & Sons, Chichester.