How to smooth your fMRI data?

A comparison between Gaussian and Adaptive Smoothing

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You smooth your data ...

... to accomodate for intersubject variation in brain anatomy
... to increase the signal-to-noise ratio (SNR)
... to enhance inference from Random Field Theory

Spatial smoothing is mostly performed during the pre-processing stage of the data analysis, however has a significant influence on the sensitivity and specificity of the activation detection analysis.

Case 1: activated regions that differ in size

All simulations were performed in R (http://www.r-project.org). The data were generated using neuRosim (Welvaert et al., 2011) and analyzed and smoothed with fmri (Tabelow and Polzehl, 2011).

- block design with 3 activation blocks (15 scans each) and 2 activated spheres (radius 3 and 5 resp.)
- rich noise including temporal and spatial correlations and physiological noise
- 4 smoothing conditions

Which smoothing method results in the highest power and lowest false positive rate (FPR)?

Case 2: neighbouring regions

- block design with 2 conditions: 5 activation blocks (10 scans and 7 scans each resp.)
- 2 activated regions (6x6x6 cubes) next to each other accounting for activation based on condition 1 and 2 resp.
- same noise model as in simulation 1
- 2 smoothing conditions

Which smoothing method results in the highest power and lowest FPR for the contrasts of each condition separately?

Spatial smoothing methods

Non-adaptive smoothing applies a Gaussian smoothing kernel with a pre-defined Full-Width Half-Maximum (FWHM). The amount of smoothing typically matches the spatial extent of the signal of interest.

(see for example Worsley, 2003)

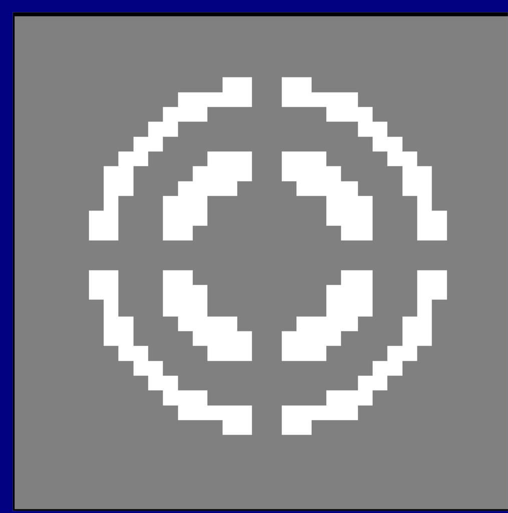
Structural adaptive segmentation takes into account the functional boundaries of the activated region and avoids loss of information on spatial extent and shape. Local kernel weights are determined in an iterative process.

(see Polzehl et al., 2010)

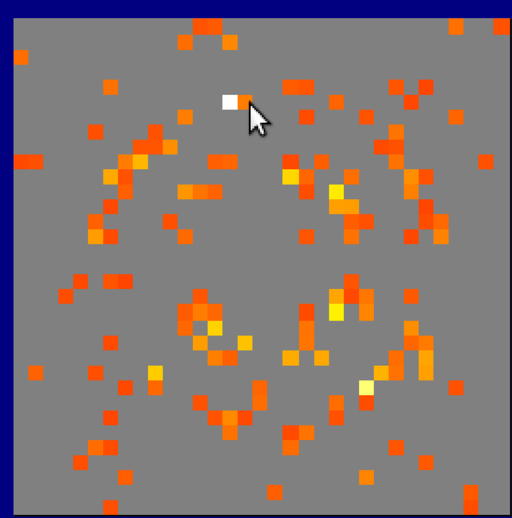
Example

Analysis of an artificial fMRI experiment in a central slice (real activation on the right). The results of the voxelwise analysis are displayed below. From left to right, the results without smoothing, for Gaussian (non-adaptive) smoothing and for structural adaptive smoothing.

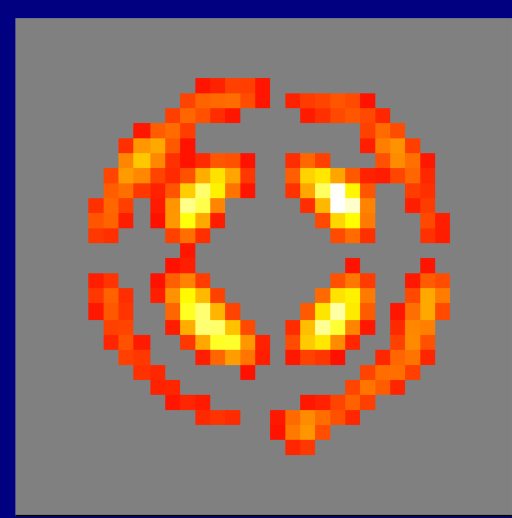
Tabelow et al. (2006)



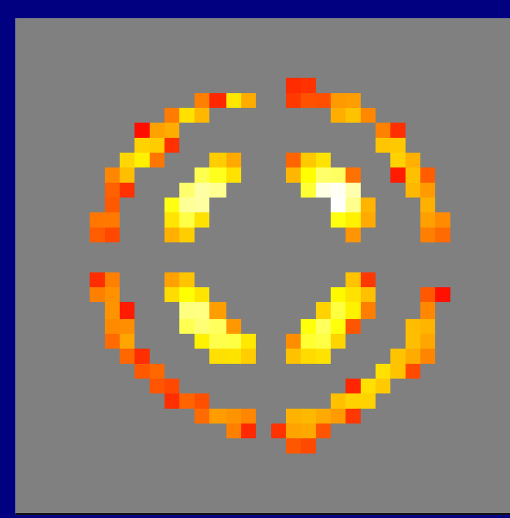
Ground truth



No smoothing

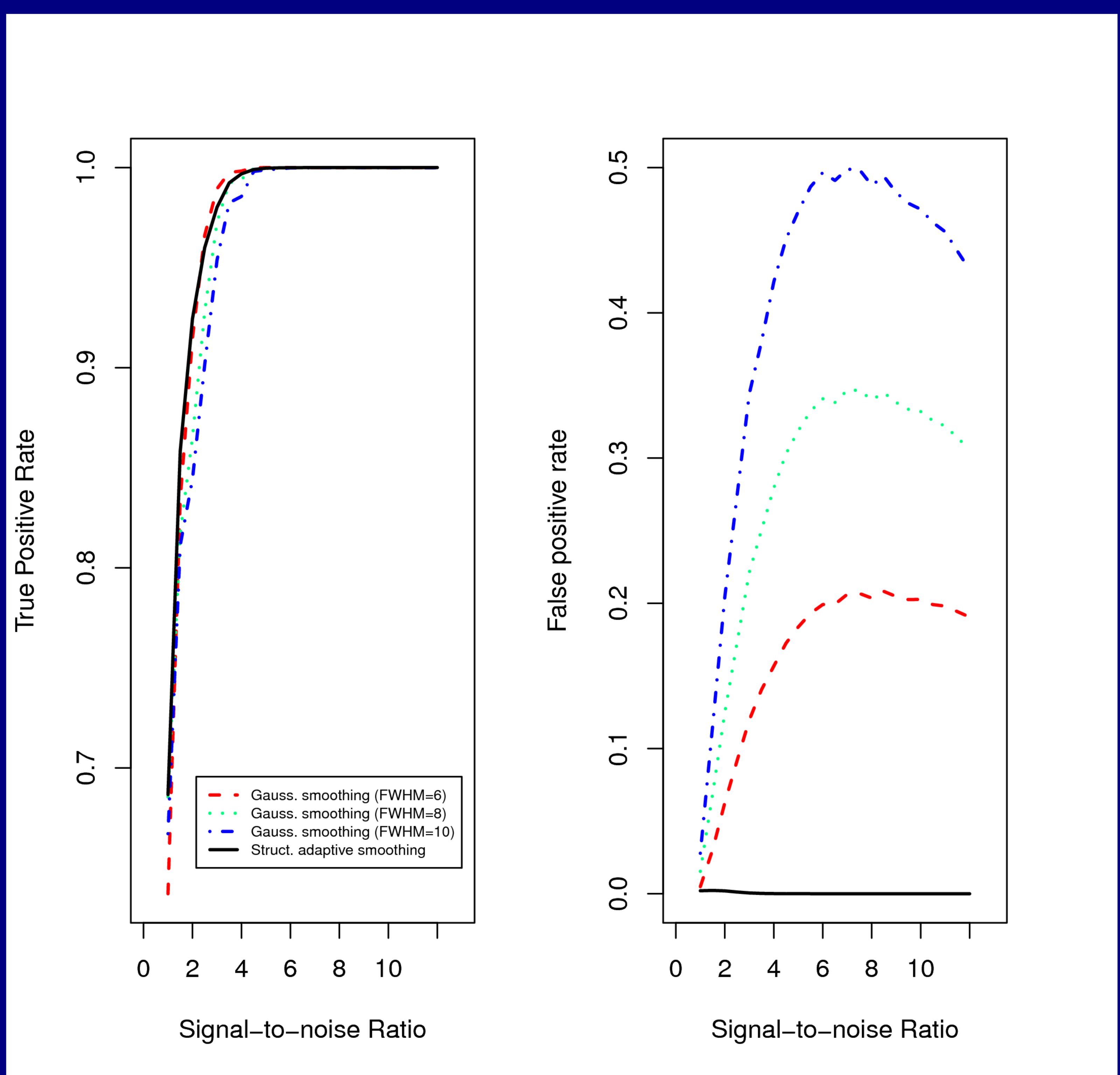


Gaussian smoothing

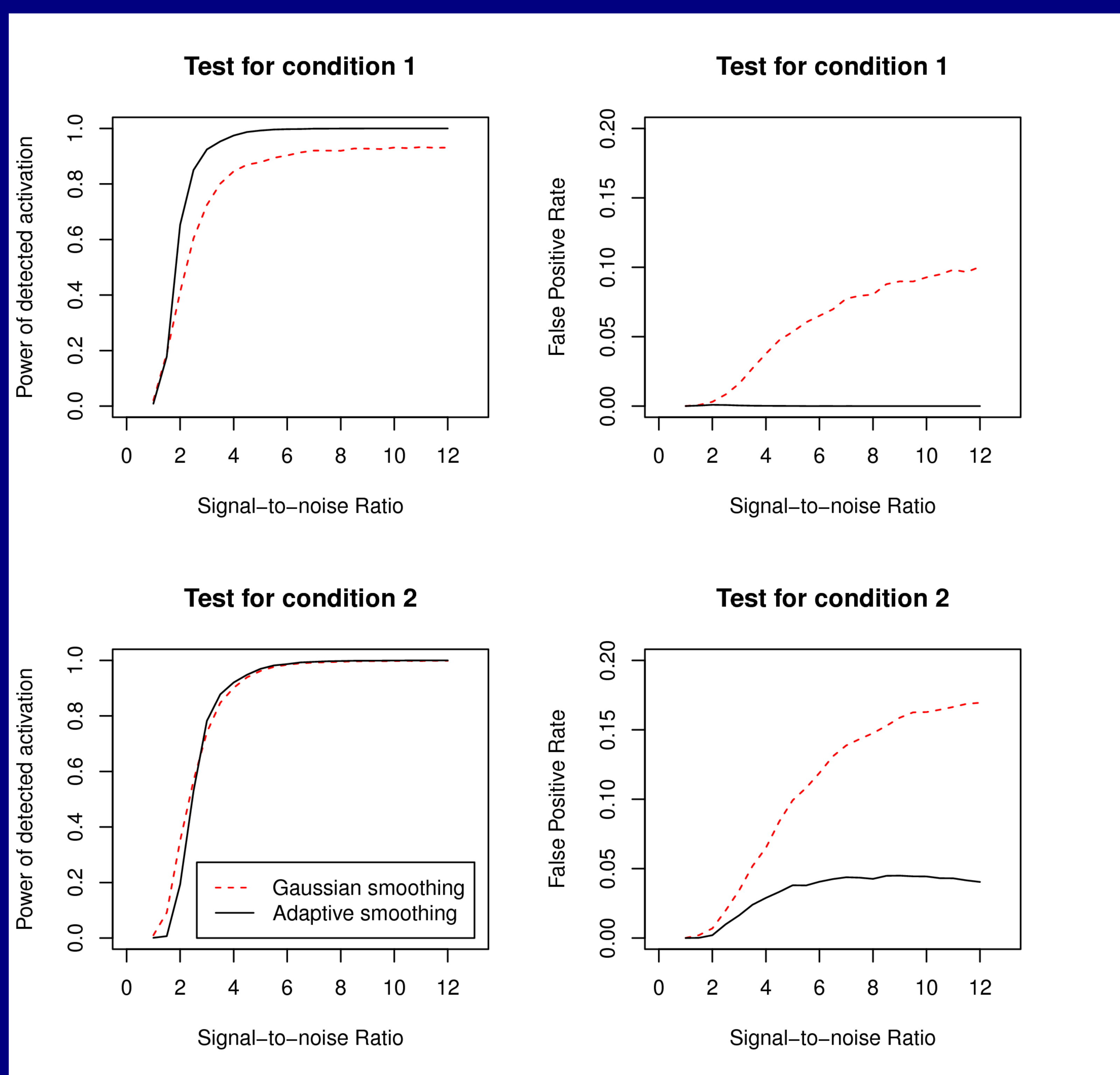


Adaptive smoothing

Results simulation 1



Results simulation 2



Conclusions

Both simulation studies show that structural adaptive smoothing outperforms Gaussian smoothing. When adaptive smoothing is applied higher sensitivity and specificity is obtained compared to Gaussian smoothing for a wide range of SNR values.

References

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