Reproducibility of the visualization of the rat somatosensory network using Independent Component Analysis in whole-brain fMRI

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Introduction — BOLD fMRI is an imaging technique to investigate neuronal activation. It is well known that non-noxious electrical stimulation of the rat forepaw leads to neuronal activation of the somatosensory network. However, to our knowledge, no neuroimaging studies have been able to visualize the entire rodent somatosensory network, especially the subcortical regions. This is possibly due to the small field-of-view used in most BOLD fMRI studies performed in rodents[1] and a lack of power of the data analysis methods. The reproducibility of these studies has also not been quantified. In the present study a data-driven technique (Independent Component Analysis, ICA) is used to identify the somatosensory network. Our aim is to map cortical and subcortical neuronal responses using ICA in order to obtain a whole-brain BOLD fMRI based template that can be used for future fMRI studies. Therefore we also investigate its spatial within-subject reproducibility.

Subjects and Methods — Three rats (Wistar) were sedated with medetomidine. Electrical stimulation was applied to the right forepaw (amplitude 4mA, pulse duration 3ms, frequency of 9Hz) using a block-design paradigm (20s on/40s off). All MR images were acquired on a Pharmascan 7T (Bruker) using a rat brain surface coil. Each fMRI run consisted of 170 repetitions with TR=2s, TE=18ms, voxel size=0.375mm. For each rat four GE-EPI runs were acquired with 5min of rest between runs. Data were processed with ICA, using the GIFT toolbox in Matlab. Anatomically relevant components were selected based on their spatial localization and temporal profile. Within-subject reproducibility of each component was quantified by calculating the spatial overlap between significantly activated voxels in a single run and the mean (calculated with GIFT).

Results — Significant activation was detected in all components of the somatosensory network (fig.1): contralateral forelimb region of the primary somatosensory cortex, bilateral secondary somatosensory cortex, thalamus, ectorhinal cortex, cerebellum and pons. The within-subject variability of the different components was acceptable (60-80% overlap), except for thalamus and is shown in fig.2.

Discussion — To our knowledge, this is the first fMRI study visualizing the entire rat somatosensory network. This can be attributed to the use of ICA, combined with careful positioning and the use of a dedicated rat brain surface coil in order to achieve successful whole-brain coverage. In conclusion, the obtained whole-brain fMRI-based somatosensory map may serve as a template for further fMRI studies. Nonetheless, within-subject variability should be taken into account at interpretation.

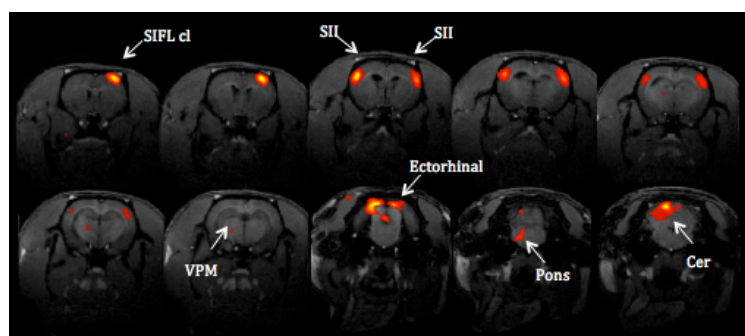[1] Zhao F. et al., 2008, Neuroimage, pp.248-260.

Figure 1. Typical findings in whole-brain BOLD fMRI during forepaw stimulation. Slices progress from most anterior at top left to most posterior at bottom right (A) The independent component maps are thresholded at p < 0.0027 and show a mean of 4 sessions within 1 subject. The contralateral forelimb region of the primary somatosensory cortex (SIFL cl), bilateral secondary somatosensory cortex (SII), thalamus (VPM), ectorhinal cortex, cerebellum (Cer) and pons are labeled with white arrows.
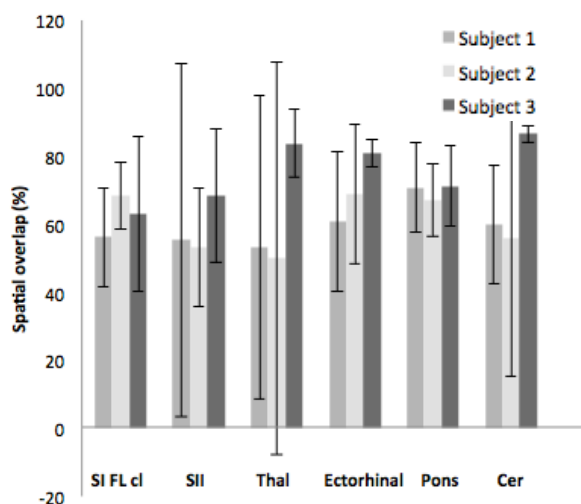

Figure 2. Spatial reproducibility across 4 runs within 3 subjects. Per component, mean and standard deviation of the spatial overlap across 4 runs are shown for the 3 subjects.