Rock-a-bye baby: using slice-by-slice motion estimation and correction to improve the sensitivity of neonatal fMRI.

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Target Audience: this research will be of interest to those researchers who study the effects of motion on functional magnetic resonance imaging (fMRI) or use fMRI to study uncooperative populations.

Purpose: fMRI has the potential to be an invaluable tool for studying brain function in patient populations with suspected brain injury; for example, neonates who are born very prematurely. However, motion remains a significant issue for neonatal fMRI because these subjects cannot be instructed to remain still, and it is often undesirable to administer sedation. Traditional rigid-body fMRI motion correction performs poorly for data sets with large or continuous motion artifacts, partly because it makes the implausible assumption that the head is stationary during each volume acquisition. As a result, slices within a volume can be out of alignment with each other, and equivalent voxels in adjacent volumes might sample different brain regions. Here, we implement a slice-by-slice motion estimation and correction algorithm to improve the detection of brain activations in fMRI data acquired from neonates.

Methods: Unconstrained nonlinear optimization is used to estimate the six parameters of rigid transformations that maximize the similarity between each slice in the fMRI time series and a template image (e.g., the mean EPI image). Given that some slices within a volume contain more information than others, multiple slices are fit simultaneously while constraining the motion trajectory to a realistic model of subject motion. A hierarchical fitting scheme that utilizes progressively smaller spatial smoothing kernels is employed to avoid local minima during the parameter estimation.

Results: Using simulated fMRI data we show that the algorithm can accurately reconstruct actual motion trajectories. So far, the algorithm has been evaluated on fMRI data collected from neonates in a somatosensory stimulation paradigm. Preprocessing included either SPM rigid-body realignment, or our slice-by-slice realignment. Data were analyzed using a standard General Linear Model that included: the predicted response, created by convolving the experimental block paradigm with an age-appropriate model of the hemodynamic response; and 6 realignment parameters. Compared to standard motion correction, our slice-by-slice method increased the peak *t*-statistic of activation in most subjects.

Discussion and Conclusion: Our model, in which motion is assumed to be continuous, performed well on simulated data and improved statistical power for detecting evoked fMRI responses in a cohort of neonates. These results suggest that the rigid-body assumption is likely to be especially poor for non-compliant populations such as infants, animals or non-communicative patients who move a lot. Our method could be of use to other researchers who study such non-compliant populations where prospective motion correction solutions are not available.