Integrated Local Correlation: a New Measure of Local Coherence in fMRI Data

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Introduction

We introduce the measure of integrated local correlation (ILC) for characterizing local coherence in the brain using fMRI data. The coupling of local neuronal processes influences coherence in a voxel’s neighborhood. Unlike existing methods of local coherence such as regional homogeneity (ReHo) [1], ILC takes into account the inherent correlation in the data, does not require the specification of a neighborhood and, as demonstrated by experimental data, is effectively independent of image resolution. Respiratory and cardiac fluctuations do not considerably alter ILC except in isolated areas in and surrounding large vessels. With resting-state fMRI data, ILC was demonstrated to be tissue-specific, higher in gray matter than white matter, and reproducible across consecutive runs in healthy individuals.

Materials and Methods

In the first experiment, EPI data were obtained from a phantom with the following scan parameters: TR= 750 ms, TE= 34 ms, FA= 50°, FOV= 22 cm, 280 volumes and voxel size of $3.44\times3.44\times5$ mm^3. In the second experiment, resting state data with the above parameters was obtained during three consecutive runs followed by a high-resolution run with an in-plane resolution of 2×2 mm^2. Low resolution data with half the resolution (4×4 mm^2) was reconstructed from the high resolution k-space data. In the third experiment, resting state data was obtained along with respiratory and cardiac pulsations and the resultant data were corrected for these fluctuations retrospectively [2]. The spatial correlation function at each voxel was obtained by calculating the temporal correlation between the voxel under consideration and its neighbors. The integration of the spatial correlation function at each voxel was defined as integrated local correlation (ILC). It was found that the phantom correlation was close to zero but significantly different from that of uncorrelated noise. Therefore we subtracted the mean spatial correlation function obtained from the phantom in ILC calculations to account for the inherent correlation in the data. Though the spatial correlation function at each voxel is ideally a continuous function with infinite support, it is discretized at the resolution of the acquired image. Also, it asympototically reaches a value of zero and hence is truncated at a finite distance. To examine the effect of these issues, ILC maps with monotonically increasing truncated boundaries were obtained from low and high resolution data as well as before and after physiological correction. The statistical significance of the difference was ascertained using the Kolmogorov-Smirnov test.

Subject	Gray Matter			White Matter		
	High Resolution	Low Resolution	p-value	High Resolution	Low Resolution	p-value
1	21.8	21.6	0.7	6.1	6.0	0.7
2	20.5	20.3	0.4	7.9	7.6	0.3
3	23.6	23.2	0.8	7.4	7.2	0.6
	Before Correction	After Correction	p-value	Before Correction	After Correction	p-value
4	21.7	22.7	0.35	11.4	12.0	0.34
5	27.9	28.1	0.76	11.8	11.7	0.89
6	26.3	26.7	0.59	8.1	8.3	0.66

Results and Discussion

The results in the Table on the right indicate that the resolution at which the spatial correlation function is measured does not significantly alter ILC as shown by its values for high and low resolution. From Fig.1 it is evident that ILC reaches a plateau after a certain distance and hence the method does not rely on the specification of a neighborhood as long as it is sufficiently large. For numerical calculations, we chose the neighborhood of 60×60 mm^2. Also, the physiological fluctuations do not have a significant effect on ILC except in isolated areas surrounding large vessels as evidenced from the p-values in the Table and Fig. 3. Tissue-specific differences of ILC shown in the Table are visually depicted in Fig.1. This tissue-specific pattern was reproducible across consecutive resting states as shown in Fig. 2. Also, voxel-wise p-values in Fig. 3 suggest that the change in ILC across runs was consistent in almost all voxels.

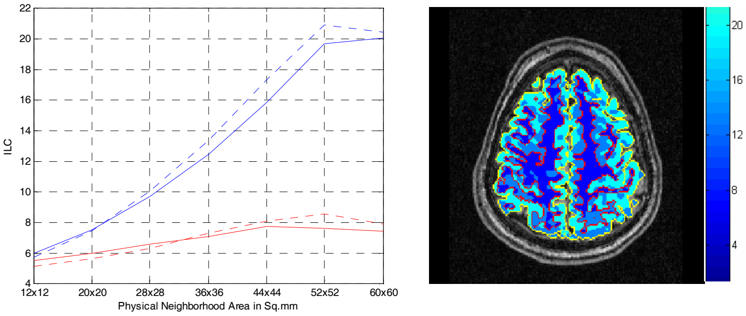

Figure 1 Left: Variation of ILC with increasing neighborhood size for both high (dotted line) and low resolution data (solid line). Blue: gray matter. Red: white matter. Right: ILC map during resting state with overlaid gray matter-white matter boundary indicating the tissue specificity of ILC

Conclusions

In this work, we have introduced a new measure for characterizing local coherence in the brain. Since the method is independent of resolution, does not require specification of a neighborhood, accounts for inherent correlation in the data and is minimally affected by physiological noise, we believe that it is a robust tool for further neuroscientific exploration of local correlation in the brain. It’s physiological relevant is demonstrated with its tissue-specificity and reproducibility

References

1. Zang et al, Neuroimage 22: 394, 2004. **2**. Hu et al, MRM 34(2): 201, 1995.

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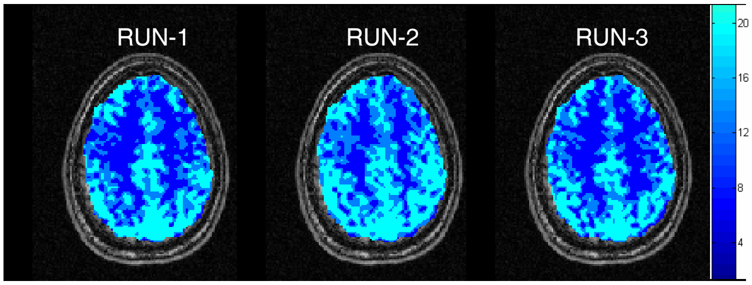

Figure 2 ILC maps for three consecutive resting-state runs in healthy individuals

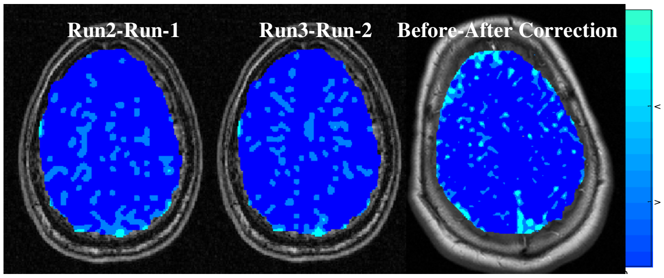

Figure 3 Significance map of voxel-wise p-values. Left, middle: resting state runs to show reproducibility. Right: The effect of physiological noise is significant only near the vessels