Local Coherence as a Measure of Localized Co-ordination in the Brain: An Application to Anesthesia

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Introduction

In this work, we introduce the concept of local coherence (LC) and demonstrate the utility of the concept with application to changes in the brain due to anesthesia. LC represents the average correlation a pixel has with its neighbors and is generated as a map over the entire brain. This is in contrast to functional connectivity which assesses the low-frequency correlation between anatomically distributed regions of the brain [1]. Our results show that the LC in the brain decreases with the application of anesthesia.

Data Acquisition

Three anesthetic states were achieved by administering 0% (awake), 2% (deep) and 1% (light) end-tidal sevoflurane to five subjects in that order. Resting state EPI data were acquired on a 3T Siemens Trio for each of the three states. Scan parameters were: TR= 750 ms, TE= 35 ms, FA= 20°, FOV= 22 cm, 10 axial slices with 5 mm thickness and 280 volumes.

Data Analysis

LC was estimated by calculating the mean of the correlation coefficients between a voxel and all its neighbors in a 3×3 neighborhood. Three slices were selected and ROIs corresponding to motor (M), supplementary motor (SMA), parietal (P) and frontal (F) areas were identified based on anatomic images. Mean LC in each ROI was calculated. The statistical significance between the differences in means for the three states was measured using Wilcoxon rank sum test [2].

		Awake		Deep		Light	
		LC	Voxels	LC	Voxels	LC	Voxels
1	M	0.35	196	0.24	28	0.30	182
	SMA	0.35	67	0.24	14	0.29	46
	P	0.36	74	0.25	9	0.33	75
	F	0.35	93	0.24	13	0.27	20
2	M	0.43	165	0.24	19	0.36	176
	SMA	0.43	74	0.24	14	0.34	59
	P	0.45	79	0.25	11	0.39	77
	F	0.48	75	0.27	15	0.29	21
3	M	0.40	213	0.20	77	0.26	149
	SMA	0.41	89	0.20	41	0.25	53
	P	0.38	51	0.22	33	0.29	50
	F	0.51	82	0.19	26	0.25	28
4	M	0.56	210	0.21	37	0.32	170
	SMA	0.58	77	0.19	20	0.30	61
	P	0.52	53	0.24	27	0.34	67
	F	0.71	88	0.15	11	0.20	12
5	M	0.31	145	0.21	32	0.29	121
	SMA	0.31	53	0.21	10	0.28	45
	P	0.31	48	0.21	12	0.30	53
	F	0.36	67	0.22	17	0.24	29

Table 1. Mean LC and number of significant voxels in the three states of anesthesia in M, SMA, P and F. $p<0.05$ for all subjects

Results and Discussion

Fig. 1 illustrates LC maps of a representative subject obtained under the awake, deep and light anesthetic conditions. This figure demonstrates that LC is reduced when going from awake to deep anesthetic condition and recovers in the light anesthetic condition. ROI results from all 5 subjects are shown in Table 1. This table shows that the results from all 5 subjects are consistent. Also, we observed that in terms of the number of significant voxels, the recovery in the light state was partial in M, SMA and complete in P whereas it was negligible in the frontal areas. This observation, which is supported by Fig.1, is significant considering the fact that the changes in the states of consciousness due to anesthesia are believed to be discrete rather than continuous [3] and that the higher functions carried out by the frontal areas were still subdued in the light state whereas sensorimotor faculties controlled by P could be fully functional under light anesthetic condition. The lack of LC in F in the light state indicated that the absence of localized coordination may hamper cortical information processing and hence LC could be used as a potential marker of the ability of cortical regions to carry out their designated functions. The phenomenon of localized disconnection that we have reported here compliments other reports of global disconnection in thalamo-cortical [4] and cortico-cortical networks [5] observed due to anesthesia.

Conclusions

In this work, we have introduced the concept of LC, which significantly decreased in the deep anesthetic state followed by a recovery in the light anesthetic state. It is interesting to note that cortical function, in particular frontal function, disintegrates with increasing anesthetic concentration.

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References

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Awake Deep Light

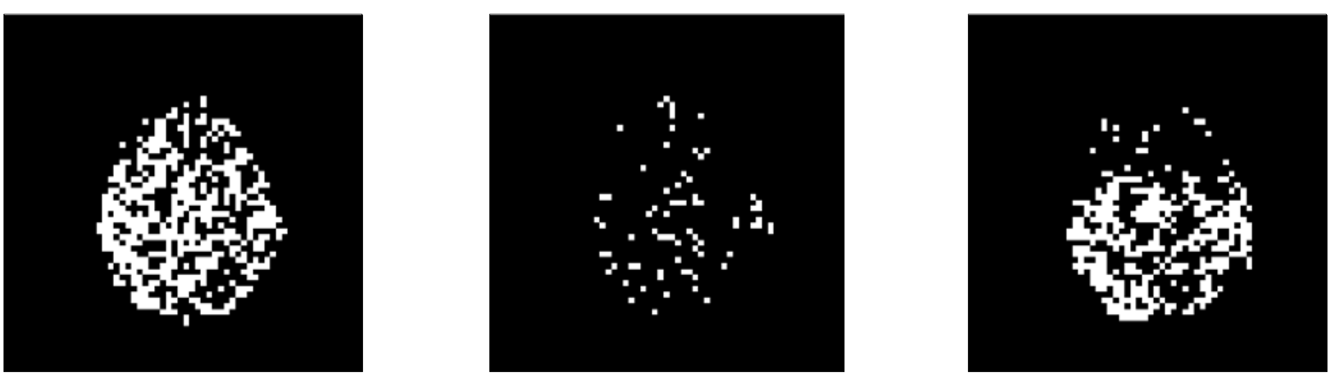

Fig.1 LC maps of significant voxels ($p<0.05$) in the awake (left), deep (center) and light (right) anesthetic conditions