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Spatial Smoothing Kernel Size Influences ICA Model Order and Spatial Maps of Intrinsic Connectivity Networks

Behnaz Jarrahi, *Member, IEEE*

Abstract— **Earlier studies indicated that fMRI preprocessing methods influence properties of intrinsic connectivity networks (ICNs). In this pilot study, we examined the effects of spatial smoothing on the network dimensionality and spatial maps. Resting state BOLD fMRI data were acquired from healthy participants with a 3.0T MRI scanner. During preprocessing, various levels of spatial smoothing were applied to the data using an isotropic Gaussian kernel with full width at half maximum (FWHM) sizes 0 to 12 mm with a step of 2 mm. Independent component analysis (ICA) was applied to derive ICNs. Results revealed that the level of spatial smoothing clearly affects the network dimensionality, intensities of spatial maps, and peak voxel location. Using minimum description length (MDL) criteria, dimensionality generally decreased as smoothing kernel size increased. In contrast, entropy-rate based order selection indicated a general increase in model order as smoothing kernel size increased. Intensities of spatial maps, which are associated with the cohesiveness and connectivity inside the network, decreased in most ICNs, including the default-mode and salience networks, as the smoothing kernel size decreased. These findings provide a preliminary insight into the effects of spatial smoothing on model order and spatial maps.**

I. INTRODUCTION

Previous fMRI research that studied effects of spatial smoothing recommend different kernel sizes ranging from 0 to 12 mm depending on analysis approach (seed-based functional connectivity vs. graph theory vs. ICA). However, the influence of spatial smoothing on the ICA model order (data dimensionality), and properties of spatial maps have not been investigated in detail.

II. MATERIALS AND METHODS

Resting state BOLD fMRI was collected from 22 healthy subjects (12 females, average age 37.73 years) on a 3.0T GE scanner. Preprocessing in SPM12 included motion and time correction, spatial normalization into the MNI reference space and spatial smoothing with an isotropic Gaussian smoothing kernel. To observe the effect of spatial smoothing, Gaussian filter kernel with full width at half maximum (FWHM) sizes 0 to 12 mm with a step of 2 mm were used. Minimum description length (MDL) criterion with independent and identically distributed (i.i.d.) samples, MDL criterion based on FWHM, entropy-rate based order selection by finite memory length model (ER-FM) and entropy-rate based order selection by autoregressive model (ER-AR) were used for estimating the number of independent source components in each dataset. Group ICA was performed with infomax algorithm in GIFT toolbox. To define significant brain regions associated with each ICN, spatial maps was normalized into *z* scores, and the averaged maps of *z* scores were entered into second-level random effects analysis in SPM12. Differences in spatial maps due to smoothing kernel size, were computed pairwise using paired *t*-test at false discovery rate (FDR) of 0.01.

III. RESULTS AND CONCLUSION

Results of model order estimation are summarized in Table 1. Using MDL criteria, ICA dimensionality generally decreased whereas the ER methods showed increased dimensionality with an increase in the smoothing kernel size. Spatial map Intensities, which can be considered as an ICA measure of within-network connectivity, decreased as smoothing kernel size decreased (Fig. 1; FDR-corrected $p < 0.01$). These results provide a preliminary overview of spatial smoothing effects on ICA model order and spatial maps.

Gaussian Smoothing Kernel FWHM (mm)	Table 1. Estimated Independent Components (IC)	Mean	Median	Std	Min	Max
	Method 1: MDL (i.i.d. Sampling)					
0	96	96.091	96	22.5724	65	147
2	111	111.32	112	20.8769	72	156
4	94	94.273	89.5	26.4308	55	166
6	96	96.455	98	14.094	65	123
8	71	71	73	10.0428	54	90
10	81	80.5	81.5	11.2027	60	104
12	65	64.682	62.5	14.5386	44	104
	Method 2: MDL (FWHM)					
0	67	66.591	63.5	14.0836	44	96
2	73	73.091	72.5	11.7874	51	99
4	82	81.727	83	11.1363	58	103
6	94	94	97	12.0673	68	115
8	41	41.364	43	5.4208	31	49
10	123	123	127	15.2815	92	154
12	139	138.73	142.5	16.5994	106	178
	Method 3: Entropy-rate Based Order Selection by Finite Memory Length Model (ER-FM)					
0	190	190	180	39.5474	130	267
2	186	185.73	179.5	33.5548	129	248
4	185	185.45	182.5	31.0479	128	241
6	193	193.14	190	29.417	140	240
8	207	206.68	207	27.2718	150	248
10	228	227.82	227	26.1345	170	269
12	248	247.82	248	21.3221	199	280
	Method 4: Entropy-rate Based Order Selection by Autoregressive Model (ER-AR)					
0	187	187.18	181.5	37.997	125	264
2	184	184.36	179.5	34.9142	126	248
4	184	184	183	30.6656	128	233
6	189	189.23	186	28.2403	134	237
8	205	204.77	205.5	27.1818	149	248
10	225	225.18	224	26.1909	173	268
12	246	246.18	247.5	22.1567	199	280

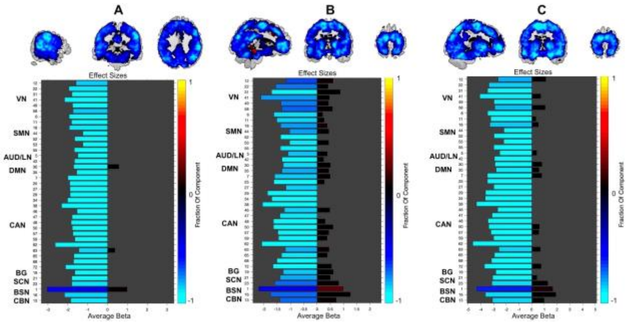

Figure 1. Significant effects of spatial smoothing kernel size on the intensities of spatial maps. Paired *t*-test results are shown for **A** S4 – S8, **B** S8 – S12, and **C** S4 – S12, where S denotes the Gaussian smoothing kernel with a FWHM of 4-, 8-, or 12-mm. FDR corrected-$p < 0.01$.

B. Jarrahi is with the Systems Neuroscience and Pain Lab, Stanford, CA, USA; (emails: behnaz.jarrahi@stanford.edu).

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