



## Effective doctor-patient communication skills training optimizes functional organization of intrinsic brain architecture: a resting-state functional MRI study

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### Abstract

We studied the influence of doctor-patient communication skills training on brain functional architecture using resting-state functional MRI (rs-fMRI) with a regional homogeneity (ReHo) method. Ten medical students participated in the study. A 1-year long doctor-patient communication skills training program was conducted. Rs-fMRI data were collected at baseline, one month and one year after training. There was a significant increase in the communication skills test average scores between baseline and 1-month duration of training ( $P < 0.001$ ). After one month of communication skills training, medical students had decreased ReHo in the right superior temporal gyrus compared with the baseline. After one year of communication skills training, students had increased ReHo in multiple regions and decreased ReHo in several regions ( $P < 0.05$ , Alphasim corrected). The change of ReHo values in the superior temporal gyrus negatively correlated with the change of communication skills scale score between one month after communication skills training and baseline ( $r = -0.734$ ,  $P = 0.036$ ). The training program we used can be an effective approach of improving doctor-patient communication skills, and the training resulted in functional plasticity of the brain's architecture toward optimizing locally functional organization.

**Keywords:** brain architecture, function, resting-state functional MRI (rs-fMRI), doctor-patient communication

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## Introduction

Doctor-to-patient communication skills in China have gained increasing attention as the relationship between healthcare providers and patients have sharply deteriorated over the past decade<sup>[1]</sup>. According to a national survey administered to healthcare professionals, more than two-thirds of respondents agreed that there have been tensions and conflicts between doctors and patients<sup>[2]</sup>, violence against medical professionals has become a common phenomenon<sup>[3]</sup>, and inadequate communication with patients prevented improvement in doctor-patient relationship<sup>[2]</sup>. Consequently, this situation demands practical measures to improve doctors' caring competences and interaction skills with patients. Doctor-patient communication skills training mostly entailed both taught communication, theoretical knowledge, and practiced communication skills. Recent studies have demonstrated that communication skills training could enhance communication skills in the clinical setting and improve doctor-patient relationships<sup>[4-6]</sup>.

Our group has developed and introduced the doctor-patient communication program since 2003 to improve doctor-patient communication skills in Chinese medical students. Most medical students greatly improved their doctor-patient communication skills after systematic training<sup>[7]</sup>. However, so far, the majority of the studies reported an improvement in the skills as evaluated only by various scales or patient satisfaction questionnaires. There have been no detailed reports associating the effect of communication training and underlying neural mechanisms. The resting-state fMRI (rs-fMRI) enables a direct examination of the functional architecture of the human brain in high spatial resolution after certain training<sup>[8-9]</sup>. Effective long-term training has usually resulted in alterations of brain structure and function. For example, Wei *et al.* reported that long-term Tai Chi Chuan practice was associated with regional structural change, i.e. significantly thicker cortex<sup>[10]</sup>, and regional functional homogeneity change<sup>[11]</sup>. Gebel *et al.* found that the cerebro-cerebellar auditory-motor loop in trumpet players was activated by isolated, context-specific motor tasks<sup>[12]</sup>.

The rs-fMRI signals reflect a spontaneous neuronal activity and the physiologic processes of the human brain<sup>[13]</sup>. Among fMRI analytic methods, regional homogeneity (ReHo) developed by Zang *et al.*<sup>[14]</sup> reflects the functional coherence of a given voxel with its nearest voxels in a voxel wise analysis, assuming that the spontaneous neural activity of a given voxel is similar to its neighbors<sup>[14]</sup>. ReHo reflects the temporal homogeneity of the regional blood oxygen level

dependent (BOLD) signal. Thus, an altered ReHo may be related to changes in temporal spontaneous neural activity of a certain region.

In this preliminary study, we applied ReHo analysis to investigate changes in brain functional architecture in medical students after communication skills training. Our hypotheses were as follows: 1) the training program would improve the trainees' communication skills; 2) the training program would optimize the functional organization of intrinsic brain architecture associated with communication skills; 3) the brain activity change would associate with an improved communication skills level after intensive training.

## Materials and methods

### Ethics statement

This study was approved by the ethical committee of the Nanjing Medical University. All students were fully informed about the experimental procedures and signed a consent form.

### Subjects

From August 2011 to July 2012, ten medical students in the fourth year of their studies from the Nanjing Medical University, Nanjing, China participated in the study. There were four females and six males; their average age was 25 years (standard deviation [SD] $\pm 2$ ). All students reported themselves to be right-handed. Exclusion criteria were a history of traumatic brain injury; a neurological or psychiatric disorder; or conditions incompatible with a MRI (e.g., metal implants, claustrophobia).

### Communication skills training methods and assessment instruments

The whole communication skills training program lasted for one year. The first month of training combined theoretical and practice elements. This entailed both taught communication theory and practiced communication skills (**Table 1**). Theoretical knowledge study on communication between doctors and patients included lectures and group discussions held twice a week for 80 minutes during two consecutive weeks. A scenario simulation of communication between doctors and a standardized patient (SP) were conducted once a week for 120 minutes during two consecutive weeks. A total of four SPs participated in this study. They were volunteers recruited from the community. The recruited SPs were trained by two clinical teachers. The training lasted for three months and focused on several aspects, *i.e.*, learning the basic medical knowledge, the typical signs and symptoms of disease, the standard of inquiry

Item	Content/dedicated time
Training course	1. Theoretical knowledge included lectures and group discussion twice a week (80 minutes for each session), a total of four weeks 2. Scenario simulation using standardized patient actor once a week (120 minutes for each session) , a total of two weeks
Clinical practice with hospitalized patients	3. Clinical practice with hospitalized patients six days a week, a total of four weeks 4. Evaluation of communication skills measured using in-house developed scales 5. Clinical practice without theoretical knowledge study (the next 11 months)

and physical examination, and the patient role and evaluating students' communication skills. The SP role was defined to provide doctors with intended clinical scenario and to avoid potential rating biases with real patients. Finally, clinical practice with real hospitalized patients such as offering comfort, discussion about treatment, physical examination, and chatting during six days a week (for four weeks) was part of this training. The evaluation of communication skills was performed using in-house developed communication skills scales, simplified from the interpersonal sensitivity part of Symptom Checklist-90 (SCL-90), including 11 questions with multiple answers that were scored using a 0-4 points scale. The total score was recorded for all students. A total score ranging 0-26 points reflected poor communication skills that needed to be strengthened; 27-34 points reflected acceptable communication skills still needing to be improved; above 35 points reflected good communication skills. The content of the communication skills scales including 11 questions are shown in **Table 2**. For each student, the pre- and post-scale scores were calculated as the mean of all items. For the following 11 months, students participated in communication with patients on a daily basis in clinical practice without additional theoretical study.

### Image acquisition

All ten subjects underwent rs-fMRI before communication skills training and after one month of intensive

training. Nine subjects underwent an additional rs-fMRI after one year of communication skills training. Hence, rs-fMRI data were collected at the introduction to the training before the actual training started, after one month of intensive training and after one year of training. Images were acquired on a 3 Tesla MR scanner (Achieva 3.0 T TX dual Medical Systems; Philips Medical Systems, Eindhoven, Netherlands). All subjects were placed in an eight-channel phased array head coil and fitted to foam padding to reduce head motion, and a pair of earplugs was used to reduce scanner noise. They were instructed to hold still, keep their eyes closed but stay awake during the scanning time. A three-dimensional turbo fast echo (3D-TFE) T<sub>1</sub>WI sequence with high resolution with TR/TE = 9.8/4.6 ms; flip angle, 8°; in-plane resolution of 1.0 mm<sup>2</sup>, FOV = 256 × 256 mm<sup>2</sup>, matrix = 256 × 256, and a slice thickness of 1 mm was acquired for spatial normalization in the preprocessing step. Functional images were acquired using a gradient-echo echo-planar (GRE-EPI) sequence sensitive to blood oxygenation level dependent (BOLD) contrast (TR = 2,000 ms, TE = 30 ms, flip angle = 90°, FOV = 192 × 192 mm<sup>2</sup>, matrix = 64 × 64, slice thickness = 4 mm). Each brain volume comprised of 35 axial slices and each functional image comprised of 240 volumes. The sections were approximately aligned with the anterior commissure-posterior commissure line and covered about -30 to 60 mm in the inferior-superior direction. Each fMRI scan lasted 480 seconds.

1. Do you think this student is good at communicating with other students?
2. Do you think this student is good at communicating with teachers or healthcare providers?
3. Do you think this student is good at communicating with patients and their families?
4. Do you think this student is good at communicating with strangers?
5. Do you think this student likes expressing himself or herself in class or at the meeting?
6. Do you think this student usually pays attention to polite manners?
7. Do you think the people who know this student understand his thoughts and emotions?
8. What do you think of this student's oral expression ability?
9. Do you think this student is rich in body language (expression, movement, tone, etc)?
10. Do you think this student often complains about patients or social environment?
11. What do you think of this student's ability to control his or her emotions?

### Functional image pre-processing

Resting state data were analyzed using Data Processing Assistant for Resting State fMRI Advanced edition (DPARSFA\_V2.2; <http://www.restfmri.net>) and Resting-State fMRI Data Analysis Toolkit (REST1.8; <http://www.restfmri.net>). Programs were run using Statistical Parametric Mapping (SPM8; <http://www.fil.ion.ucl.ac.uk/spm>), based on the Matlab platform (The Mathworks Inc., USA). The first ten volumes were discarded for signal equilibrium and participants' adaptation to the scanning. The remaining 230 volumes were further analyzed. Standard steps of slice timing, head motion correction, and spatial normalization to the standard Montreal Institute (MNI) template using T<sub>1</sub> segment information with a resampled voxel size of 3\*3\*3 mm<sup>3</sup> were performed. Finally, the REST toolkit (<http://resting-fmri.sourceforge.net>) was used to remove the linear trend of time courses and for temporally band-pass filtering (0.01-0.08 Hz) that reduces low-frequency drift and physiologic high frequency respiratory and cardiac noise.

### ReHo analysis

ReHo analysis was performed for each subject using the REST software. A Kendall's coefficient of concordance (KCC) (also called ReHo value) was calculated to measure the similarity of the ranked time series of a given voxel to its nearest 26 neighbor voxels in a voxel-wise way. Through calculating the KCC value of every voxel in the whole brain, an individual ReHo map was obtained for each subject. The intracranial voxels were extracted to make a mask<sup>[15]</sup>. For standardization purposes, each individual ReHo map was divided by its own mean ReHo within the mask. Spatial smoothing was then performed with a Gaussian kernel of 6 mm full-width at half-maximum (FWHM).

### Statistical analysis

Statistical analysis was performed using SPSS software version 16.0 (SPSS Inc. Chicago, IL) for demographic and clinical data, and SPM8 (statistical parametric mapping, <http://www.fil.ion.ucl.ac.uk/spm/>) for fMRI data. The growth in their average score over all items of communication skills scale between one month after communication skills training and baseline was tested with paired *t*-tests (significance level of 0.05). To examine the effect of communication skills training on brain function, repeated measures ANOVA was performed for differences in ReHo values pre- and post-training in a voxel-wise manner. To correct for multiple comparisons, we used the Alphasim program set at  $P < 0.01$  and cluster size  $> 837 \text{ mm}^3$ , which corresponded to a corrected  $P < 0.05$ . Regions showed

significantly altered ReHo in the one month follow-up and baseline comparison were selected as seed regions, and then ReHo values were extracted from these seed regions within each subject. Supposed that the one month follow-up and baseline differences of ReHo, communication skills scale scores are expressed as  $\Delta\text{ReHo}$  and  $\Delta\text{communication skills scale scores}$ , respectively. The correlations between them were calculated by crossing subjects. Correlation analysis was performed using SPSS 16.0 (SPSS Inc., Chicago, IL), significant level of *P* values was set at less than 0.05.

### Results

The demographic characteristics and average score over all items of the self-made communication skills scale of all students are summarized in **Table 3**. Improvement in the average score of communication skills training between baseline and after one month of training was significant ( $P < 0.001$ ).

After 1 month of communication skills training, students had decreased ReHo in the right superior temporal gyrus (STG) compared with the baseline. ( $P < 0.05$ , Alphasim corrected) (**Fig. 1, Table 4**) After one year of training, students had increased ReHo values in multiple regions: the superior frontal gyrus (SFG), inferior frontal gyrus (IFG), middle frontal gyrus (MidFG), medial frontal gyrus (MFG), anterior cingulate cortex (ACC), thalamus, amygdala, and insula. Decreased ReHo values were observed in the posterior cingulate cortex (PCC) and parahippocampal gyrus ( $P < 0.05$ , Alphasim corrected) (**Fig. 2, Table 4**). As we were focused on the differences between one month and one year with the baseline, we only showed these two results in the manuscript. The difference between one year and one month is shown in the supplementary figure.

The change of ReHo values in STG was negatively correlated with the change of communication skills scale score between one month after communication skills training and baseline ( $r = -0.734$ ,  $P = 0.036$ ) (**Fig. 3**).

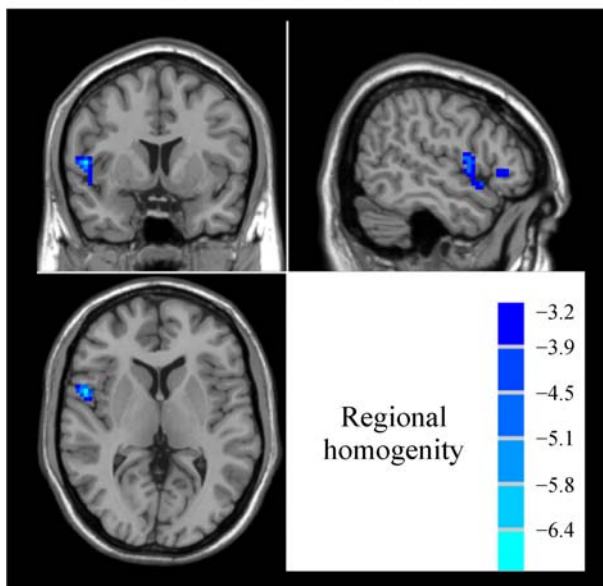
### Discussion

To the best of our knowledge, this was the first study to investigate the neurophysiological mechanism communication skills improvement after a specialized communication skills training in medical students. After one month of intensive training, the scores on communication skills scale significantly improved compared with baseline. The brain activity on rs-fMRI

	baseline (n = 10)	1-month after training (n = 10)	1-year after training (n = 9)	P- value
Gender (M/F)	6/4	6/4	5/4	
Age (y,±SD)	25±2	25±2	24±2	
Education(y±SD)	17±1.32	17±1.32	17±1.18	
Scale for each subject				
Subject 1	28	34		
Subject 2	31	33		
Subject 3	28	34		
Subject 4	31	35		
Subject 5	33	35		
Subject 6	30	33		
Subject 7	30	33		
Subject 8	32	35		
Subject 9	31	33		
Subject 10	30	34		
Scale (±SD)	30.40±1.58	33.90±0.88		< 0.001*

Values are expressed as mean±SD.  
\*The P value was obtained by paired t-test in comparison with the communication skills scale score between baseline and 1-month after training.

### 1-month vs. baseline



**Fig. 1 Regional differences in ReHo after 1 month of communication skills training compared with baseline.** After 1 month of communication skills training, the medical students had decreased ReHo in the right superior temporal gyrus (STG) compared with the baseline ( $P < 0.05$ , Alphasim corrected). Blue area represented that the ReHo value in the right superior temporal gyrus (STG) at 1 month follow-up was lower than that of the baseline.

derived from ReHo analysis showed significant change in local functional organization between the baseline

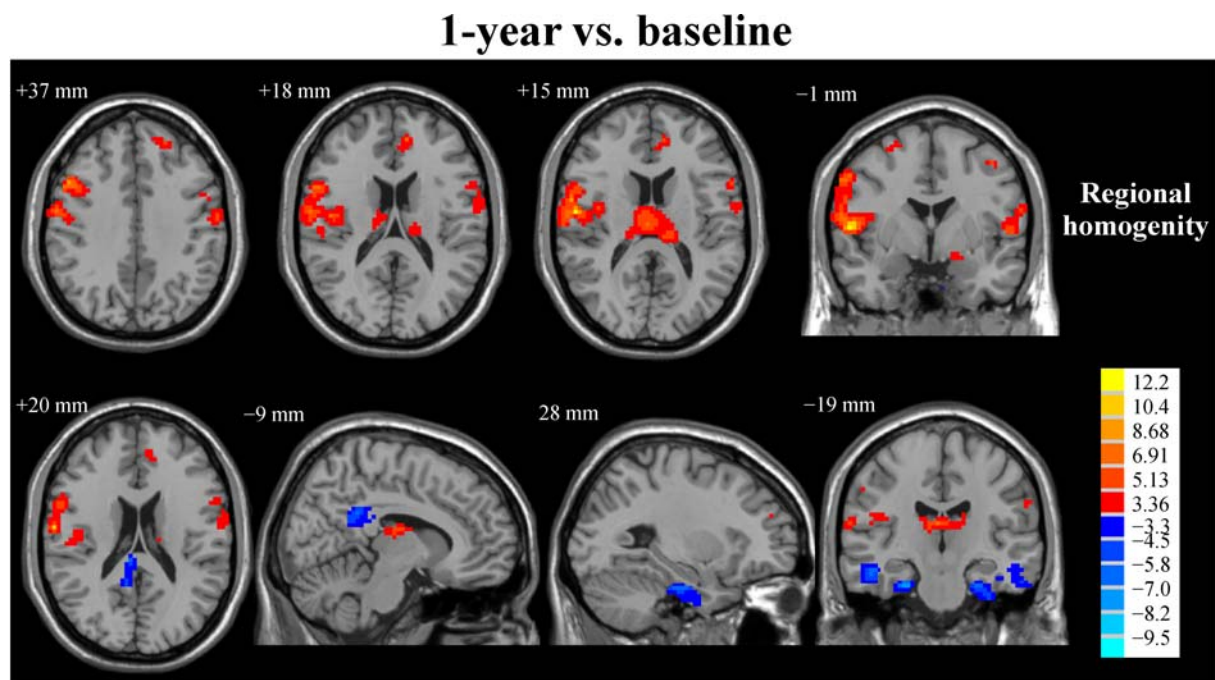
and one month of training duration. Specifically, medical students had lower ReHo in the right STG. Moreover, after one year of training, the students had increased ReHo in multiple brain regions and decreased ReHo in PCC and parahippocampal gyrus. The change of ReHo values in STG was negatively correlated with the change of communication skills scale score between one month after communication skills training and baseline.

Communication is not a skill that develops automatically over time and with experience<sup>[16]</sup>. Many studies consistently suggested that communication skills can be taught and the mastered competence can be retained over years<sup>[17]</sup>. After one year of training, medical students attained significant improvement in communication skills, indicating that the combination of theoretical and practical training program we used did have a positive effect on improving doctor-patient communication. Both improved functional specialization (decreases in functional homogeneity) and improved functional integration (increases in functional homogeneity) were detected using rs-fMRI. These findings support the notion on functional plasticity of the brain's intrinsic architecture toward optimizing locally functional organization. In a research focused on brain activity in adult instrumental musicians, Schlaug *et al.* reported that the musicians showed functional changes in related areas 14 months after baseline rs-fMRI, whereas no significant changes were

**Table 4** Brain regions showing ReHo differences from baseline and after one month and one year of communication skills training.

Brain region	MNI coordinates (mm)	Vol (mm <sup>3</sup> )	Maximal T-value
	(x, y, z)		
<b>One month vs. baseline</b>			
STG (R)	54, 6, 6	1,215	-7.1268
<b>One year vs. baseline</b>			
IFG (R)	48, 15, 37	3,888	6.9362
ACC (L)	-15, 42, 18	891	6.921
MFG (L)	-15, 42, 15	1,890	6.921
Thalamus (L)	-12, -22, 15	1,998	7.0368
Thalamus (R)	-12, -22, 15	1,782	7.0368
Amygdala (L)	-30, -15, -24	864	3.3554
Insula (R)	40, -13, 15	1,782	10.274
MidFG (R)	47, 14, 40	2,187	10.274
SFG (R)	21, -9, 69	2,727	6.921
PCC	15, -48, 21	1,485	-6.6008
Parahippocampal	26, -12, -30	999	-7.965
Parahippocampal	-24, -12, -27	1,539	-7.029

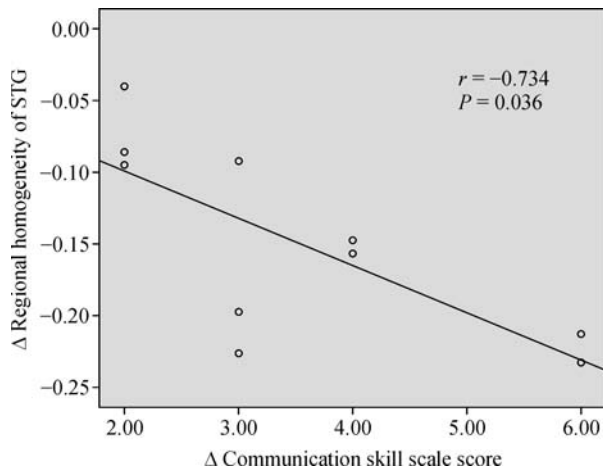
Positive values are increased in ReHo. Negative values are decreased in ReHo. ReHo = Regional homogeneity; MNI = Montreal Neurological Institute; IFG = inferior frontal gyrus; ACC = anterior cingulate cortex; MFG = medial frontal gyrus; MidFG = middle frontal gyrus; SFG = superior frontal gyrus; PCC = posterior cingulate cortex.  $P < 0.05$ , Alphasim corrected.



**Fig. 2** Regional differences in ReHo after 1 year of communication skills training compared with baseline. After 1 year of communication skills training, the participants had increased ReHo in the superior frontal gyrus, inferior frontal gyrus, middle frontal gyrus, medial frontal gyrus, anterior cingulate cortex, thalamus, amygdala, and insula. Decreased ReHo was observed in the posterior cingulate cortex and parahippocampal gyrus ( $P < 0.05$ , Alphasim corrected). Blue area represented that the ReHo value in those areas at 1 year follow-up was lower than those of the baseline. Red area represented that the ReHo value in those areas at 1 year follow-up was higher than those of the baseline.

seen in the control group<sup>[18]</sup>. Therefore, although our study did not include a control group for comparison, we suggest that the alteration of brain activity might be due to the specific training program.

Medical students had increased functional homogeneity in SFG, IFG, MidFG, MFG, ACC, thalamus, amygdala, and insula after one year of communication skills training. This ReHo increase might be associated



**Fig. 3 Correlation between the changes of ReHo in STG and changes of communication skill scale scores between 1 month after communication skills training and baseline.** The change of ReHo values in STG was negatively correlated with the change of communication skill scale score between 1 month after communication skills training and baseline ( $P < 0.05$ ). STG = superior temporal gyrus;  $\Delta$  = the difference of communication skill scale score and ReHo between 1 month after communication skills training and baseline.

with an improvement in the integration of the emotional intelligence and social cognition functions attributed to the aforementioned brain areas. The amygdala is one of the core structures of emotion processing<sup>[19]</sup>. It is hypothesized that a larger amygdala allows for greater emotional intelligence and enables greater social integration and cooperation with others<sup>[20]</sup>. The amygdala, thalamus, ACC, and frontal regions are all involved in the limbic system critical in emotion, motivation, attention, and formation of memory processes<sup>[21]</sup>. The insular cortex is considered as an integration center of external events and internal cognitive processing, and plays an important role in various emotional and cognitive functions<sup>[22]</sup>. Dysfunction of the insular has been reported in many emotion-regulated diseases such as major depressive disorder. Good communication combines a set of skills including non-verbal communication, attentive listening, and ability to build up trust and respect, and emotion handling. Therefore, we suggest that communication skills training enhanced students' communication skills by functional reorganization, supported by the negative correlation between the change of ReHo values in STG and change of communication skills scale scores between one month after communication skills training and baseline.

The doctor-patient communication skills training optimizes the functional specialization of emotional intelligence and social cognition areas. The decreased ReHo in the STG, PCC and parahippocampal gyrus

during the training indicated that medical students after training may have changed functional homogeneity within these areas, in terms of improvement of functional specialization. The PCC forms a central node in the default mode network of the brain, and it has been implicated as a key part of several intrinsic control networks<sup>[23]</sup>. In addition, it has also been linked to emotional salience<sup>[24]</sup>. The STG has been involved in the perception of emotions in facial stimuli<sup>[25]</sup>. Moreover, STG has been discovered to be an important structure in the pathway consisting of the amygdala and prefrontal cortex, which are all involved in social cognition processes<sup>[26]</sup>. The parahippocampal gyrus plays an important role in memory encoding and retrieval, and may play a crucial role in identifying social context, including paralinguistic elements of verbal communication<sup>[27]</sup>. These high-level associative brain areas need to be highly specialized at the local micro-scale level and to segregate the actualization of different functional aspects. This may explain the detected low-functioning homogeneity in these regions.

Several studies have provided explanations for the neural substrates of plastic changes after a specific training. Plasticity is achieved both by increasing the power and the numbers of synapses specifically supporting a progressively improving behavior. The magnitude of such changes can be remarkable: a large proportion of synapses are altered in their connection strengths as one acquires any significant skills or ability<sup>[28]</sup>. Through Hebbian network plasticity, the extensively cross-wired neurons in the cerebral cortex also strengthen their connections with their nearest neighbors<sup>[29]</sup>. The plasticity-driven growth in local "teamwork" is a critical aspect of the improvement in any learning-based advance in behavior performance in learning<sup>[30]</sup>. An important finding in our study was that after a one-year training, medical students had higher synchronization of several key brain regions involved in communication skills. ReHo indicates temporal similarity or synchronism between a single voxel and its neighboring voxels and the coordinated function of the spontaneous neural activity. Thus, we speculate that higher synchronization among these brain regions in our study might result from plastic changes after training.

Our study had some limitations. First, this study is preliminary and our results are limited to a small sample size, which may affect the statistical power and comprehensive interpretation of the results. Further studies with more participants are needed. Second, we did not have a control group without any special training for comparison. However, there have been studies showing that control subjects without special training did not express any significant functional

changes. Further studies should enroll a control group to give more comprehensive and accurate results in brain function and behavior. Third, the communication skills scale used in our study was simplified from the interpersonal sensitivity part of Symptom Checklist-90 (SCL-90). As this was a pilot study, there were only a few subjects included, and the reliability and validity were not tested. We will test the reliability and validity using a large sample in the future. Finally, we did not evaluate patient health outcomes such as adherence and symptom resolution. As patient satisfaction and health outcomes are the key indicators for improving doctor-patient rapport, we recommend that future doctor-patient communication studies should include these evaluations.

In conclusion, the training program we used might be an effective approach of improving doctor-patient communication skills. Our fMRI findings indicated that training resulted in functional organization of intrinsic architecture and at least some plastic changes in several key brain regions can occur over a long period of time with specific training.

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