Introduction:

The functional brain connectivity changes over time even during rest. This change of network depends on the individual characteristics such as age and disease severity. In this study, we assume that the change of shape in the dynamics of resting-state functional connectivity is associated with age. The topological data analysis can quantify the shape of network by mapping into persistence diagrams (PDs). It also provides a tool for measuring the difference between shapes, called persistence scale space (PSS) kernel [1]. We extend the PSS kernel to multiple PSS kernel by combining two different kernels that have different shape information of connected components and holes. Using the multiple PSS kernel, we define a new measure, called shape variability, to estimate how much the network changes during the resting-state. The larger the shape variability is, the more the network changes during the resting-state. In experiments, the proposed method is applied to resting-state fMRI data of 38 healthy normal subjects from 20s to 60s. The result shows that as the subject gets old, the functional brain network changes more during the resting-state.

Methods:

Datasets:
The fMRI data set consists of 38 (M/F: 19/19, age: 43.85±13.86) healthy normal subjects. 112 volume of MR images were acquired from each subject for 6.7 minutes (Siemens Biograph mMR 3T scanner). After preprocessing by AFNI and FSL, the mean BOLD signals in 90 regions of interest (ROIs) defined by automated anatomical labeling (AAL) template were estimated.

Overall procedure of the proposed methods are shown in Fig. 1.

* Dynamic brain network: We computed the sequence of functional brain networks per subject using the sliding-window analysis (the window size was 40 images and 30 images were overlapped). Then, 8 dynamic functional brain networks, N1, ..., N8 were constructed for each subject.
* Persistence diagrams: The shape information of connected components and holes in each network was encoded in the PDs P0 and P1, respectively.
* PSS kernels for connected components and holes: Two 8X8 kernel matrices K0 and K1 of N1, ..., N8 were calculated based on the persistence scale space (PSS) kernel [1]. K0 and K1 are a kernel matrix of P0 and P1 of 8 networks, respectively.
* Multiple kernel: Because the kernels are additive, we added two kernels by $K = \alpha K0 + (1-\alpha)K1$ (0≤\alpha≤1) and estimated the distance between two networks, d(Nt,Nt+1).
* Using the kernel $K$ and the distance $D$:
  - We can visualize the trajectory of dynamic resting-state functional brain network by transforming the networks into points in 2-dimensional space (Fig. 2(a)).
  - The shape variability is defined by $\sum t d(N_t, N_{t+1})$. The larger the shape variability is, the more the shape of functional network changes during the resting-state (Fig. 2(b)).
  - By applying kernel k-means clustering, the networks can be clustered according to their connected component and hole structures.

![Diagram of the proposed method](image)

**Results:**

Using the multiple PSS kernel $K$ with $\alpha=0.2$, we drew the trajectory of change of brain network during rest in the 2-dimensional space (Fig. 2(a)). The larger the shape variability is, the longer the trajectory is. The shape variability is proportional to age ($p = 0.038$, Fig. 2(b)).
Conclusions:

In this study, we propose a new method to measure the change of shape of functional brain network during the resting-state. By introducing the persistence diagram and multiple PSS kernel, we can visualise the trajectory of change of shape of networks and measure the shape variability during rest. The shape variability is related to age. It means that as the subject gets old, the shape of functional connectivity changes more during the resting-state. It is known that the normal aging is related to a decline in information processing of brain. In the future, we will try to find the relationship between shape variability and inefficient information processing of functional brain network.

Imaging Methods:

BOLD fMRI

Lifespan Development:

Aging

Modeling and Analysis Methods:

fMRI Connectivity and Network Modeling
Task-Independent and Resting-State Analysis

Poster Session:

Poster Session - Wednesday

Keywords:

Aging
Data analysis
FUNCTIONAL MRI
NORMAL HUMAN
Other - Connectivity

\[1^{2}\] Indicates the priority used for review

**Would you accept an oral presentation if your abstract is selected for an oral session?**

Yes

**I would be willing to discuss my abstract with members of the press should my abstract be marked newsworthy:**

Yes

**Please indicate below if your study was a "resting state" or "task-activation" study.**

Resting state

**Healthy subjects only or patients (note that patient studies may also involve healthy subjects):**

Healthy subjects

**Internal Review Board (IRB) or Animal Use and Care Committee (AUCC) Approval. Please indicate approval below. Please note: Failure to have IRB or AUCC approval, if applicable will lead to automatic rejection of abstract.**

Yes, I have IRB or AUCC approval

**Please indicate which methods were used in your research:**

Functional MRI

**For human MRI, what field strength scanner do you use?**

3.0T

**Which processing packages did you use for your study?**

AFNI
FSL

**Provide references in author date format**