

Lyapunov exponent analysis of brain cortical resting-state fMRI signals in older adults

with significant memory concern



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Introduction

- ❖ Scientists believe that it's quite necessary to intervene in the Alzheimer's disease (AD) progression as early as possible to have effective treatments. The best time should be even before clinical symptoms, which is defined as significant memory concerns (SMC). There are increasing evidences showing that SMC is a potentially valid early clinical marker of brain and cognitive changes.
- ❖ A system possessing at least one positive Lyapunov exponent is chaotic. Lyapunov exponents are usually ordered in a descending fashion from L1 (the highest value) to Ln (the lowest value). The larger the positive L1 of the time series, the more complicated the behavior of the nonlinear system. A number of studies focused on largest Lyapunov exponent have shown the smaller L1 and decreased nonlinear processes underlying the EEG in AD.
- ❖ We hypothesized that there might be some differences when comparing the largest Lyapunov exponent of brain cortical resting-state fMRI time series of SMC and healthy people.

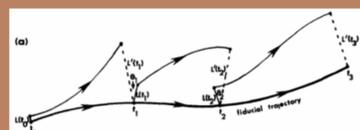
Methods

All the resting-state fMRI Data of 50 subjects from the longitudinal Alzheimer's disease Neuroimaging Initiative (ADNI) are used, included 23 SMC (12 females and 11 males, mean age=71.75 yrs) and 27 NC (age-matched healthy normal controls, 15 females and 12 males, mean age=70.88 yrs).

All the data preprocessing has been done by SPM12 (Statistical Parametric Mapping 12, released 2014) software. DKT (Desikan–Killiany–Tourville) Atlas is applied to the parcellation of brain cortex. The largest Lyapunov exponent analysis are performed with MATLAB. Statistical analysis are performed with JMP software.

Estimating the Lyapunov exponents from a time series happens roughly in two steps:

- 1) Reconstructing the phase space from the time series: Reconstruct higher-dimensional state space from a 1-dimensional time series by lagging the data, e.g. taking $x(t)$ and turning it into a series of vectors $[x(t), x(t+T), \dots, x(t+nT)]$.
- 2) Estimating the Lyapunov exponent from this reconstructed phase space.

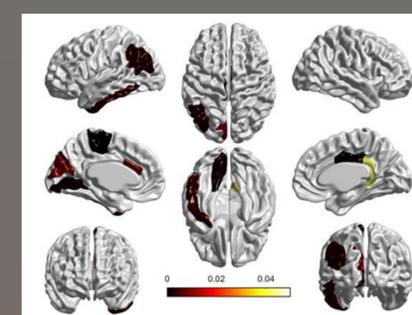
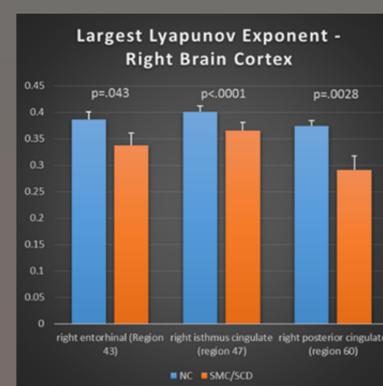
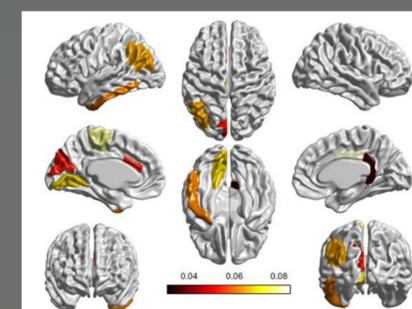
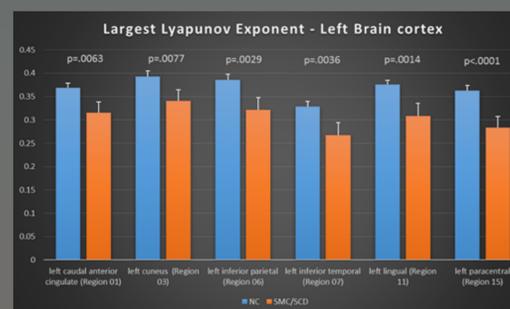


$$\lambda_1 = \frac{1}{t_M - t_0} \sum_{k=1}^M \ln \frac{L'(t_k)}{L(t_{k-1})}$$

Results

In 9 of all 62 brain cortical regions (6 regions in left hemisphere and 3 regions in right hemisphere) from DKT atlas, the largest Lyapunov exponents of brain cortical resting-state fMRI time series of SMC people are significantly smaller than the normal control ones, which indicates the less complicated behavior and reduced function of the SMC brains.

5 of the 9 regions, including left cuneus, left inferior temporal, left lingual, right entorhinal and right posterior cingulate are functionally related to memory (include working memory, visual memory and memory retrieval), while having other important brain functions. The other 4 regions are related with attention, emotion, perception, decision-making, motor and sensory innervation, etc.



Conclusions

- The preliminary results suggest the significant differences of the largest Lyapunov exponent of resting-state fMRI time series from 9 cortical brain regions related to memory, emotion, perception, decision-making and other important brain functions, of older SMC and age-matching healthy people.
- Nonlinear dynamics analysis could be used as effective clinical diagnosis criteria of SMC, and help us to determine the best time to intervene in the disease progression of dementia.

References

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