功能性磁共振响应与动态视觉特征在自然视觉条件下的关系

Relationship between functional MRI response and dynamic visual features during natural viewing in the macaque

Linxi Li[2], Xufeng Zhou1[1,2], Lei Wang[1,2] , Jie Yang[1,2], Ortiz-Rios-Michael[4], Sze Chai Kwok[1,2,5]

1 Shanghai Key Laboratory of Brain Functional Genomics, Key Laboratory of Brain Functional Genomics Ministry of Education, Shanghai Key Laboratory of Magnetic Resonance, Affiliated Mental Health Center (ECNU), School of Psychology and Cognitive Science, East China Normal University, Shanghai, China; 2 Division of Natural and Applied Sciences, Duke Kunshan University, Duke Institute for Brain Sciences, Kunshan, Jiangsu, China; 3 NYU-ECNU Institute of Brain and Cognitive Science at NYU Shanghai, Shanghai, 200062, China;

4 University of Perugia, Perugia, Umbria, IT Functional Imaging Laboratory, German Primate Center, Leibniz Institute for Primate Research, Germany 5 Shanghai Key Laboratory of Magnetic Resonance, East China Normal University, Shanghai, 200062, China;

Introduction

This project aims to evaluate the relationship between low-level features, high level features of the videos and their possible impact on BOLD signal with Statistical approach.

此研究旨在用统计学手段评估在自然视觉中视频的低级特征和高级特征对于猕猴BOLD信号以及全脑连接性的影响。

Background

Functional magnetic resonance imaging (fMRI) is becoming a popular non-invasive tool for imaging functionally active brain regions in health and in disease. And BOLD(**blood** oxygen level dependent) signal was one of the most important indicator that dominates the fMRI field. However, only few researchers has researched on the relationship between time-series video watching and their corresponding BOLD signals.

功能性磁共振成像是最普遍的非侵入性功能性大脑区域成像工具，而BOLD信号是最重要的fMRI领域最重要的指标之一. 然而，只有少量研究关注了时间序列视频和相关的BOLD信号之间的关系.

Method

1. Feature Extraction(特征提取)

Two group of videos, 9 videos in one group.
Each video is 30 seconds long, each seconds contains 25 frames.
Extracted low-level features of the videos(Optic flow, Saturation, contrast, luminance) by Python library OpenCV.
The high-level features was rated by human, high-level features included in total 52 features, including visible genitals and the number of animals in the videos.
两组视频，每组九个视频。
每个视频30秒，每秒25帧
用OpenCV来提取底层特征，研究员手动评估高级特征

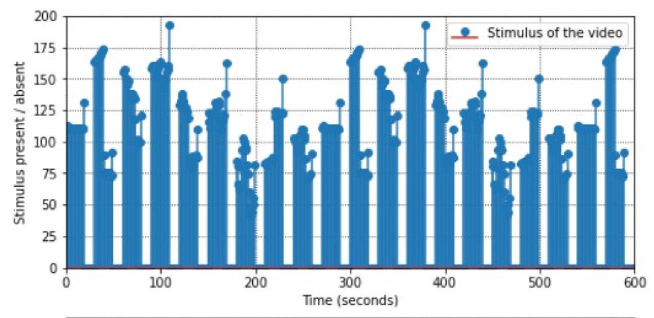

Figure1 Visualization of luminance

2.Convolution & Correlation（卷积&相关）

We convolved it with HRF(hemodynamic response function), the HRF were generated by GAMMA function(by default. Then we calculated the pearson correlation between the predicted BOLD signal and the true recorded BOLD signal.
我们将提取出的时间序列特征与血氧动力学函数卷积,血氧动力学函数由GAMMA函数生成,然后计算卷积后的数据和真实数据之间的皮尔逊相关。

3.Design Matrix & Sensitivity coefficients（设计矩阵&敏感系数）

The sensitivity coefficients were calculated by multiplying the pseudo coefficients of the design matrix and the recorded BOLD signal data of each ROI. It measures the BOLD signal sensitivity to certain features.
敏感系数用设计矩阵的伪逆矩阵和BOLD信号相乘得出.该指标表示BOLD信号对于特定特征的敏感性。

4. Regression analysis（回归分析）

The ratio of training size and the test size was 8:2, and the performance was evaluated by the variance explanation rate of the prediction of the test set's features and the measured BOLD signal.
训练集和测试集比例为8：2，用方差解释率评估性能

5.Connectivity（连接性分析）

The connectivity was calculated by the coupling() function, this function is able to calculate the connectivity between each ROIs with a sliding window.
全脑连接度用coupling()函数来计算，这个函数能够计算ROI之间的连接程度。

Results

We found that for both low-level and high-level features, two corresponding parts of left hemisphere and right hemisphere has particularly high correlation than other ROIs.
对高级特征和底层特征来说，我们发现了左右脑的两个相对区域具有明显高于其他ROI的相关度。

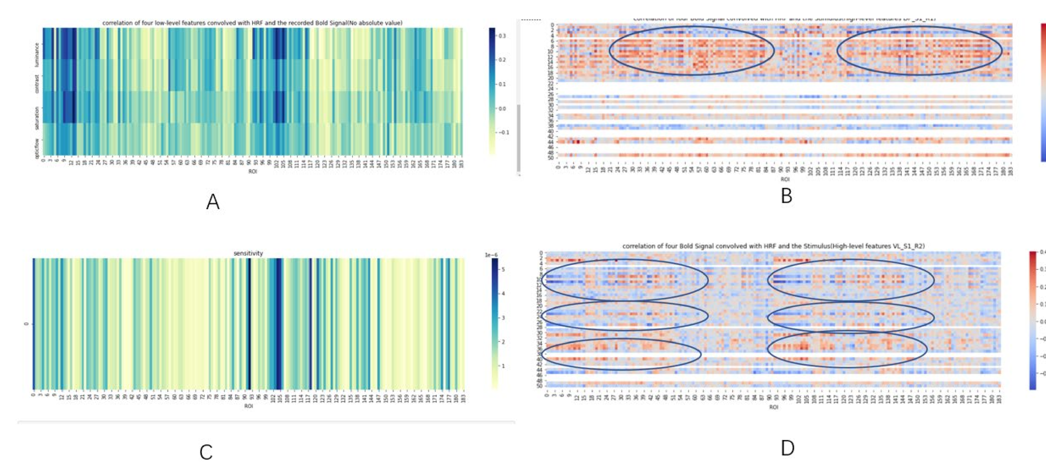

Figure2 Correlation analysis & Regression analysis A)The correlation across all 184 ROIs and 4 features B)High-level patterns in DP C) sensitivity coefficients across all 184 ROIs: luminance D) High-level patterns in VL

After performing the convolution & correlation process, we found that for low-level features, two corresponding parts of left hemisphere and right hemisphere has particularly high correlation than other ROIs.
A) The feature near ROI 14 and ROI 105 has highest correlation than other ROIs, and they are two corresponding areas between left and right hemisphere, we believed that we found a visual sensitive area of the brain. Those areas were IV4, IFST,IMT,ITAa,ITEm,rV1,rV4,Rteo,rTEa,rTEm,ITEm,IAL,rTAa.ROI14 ROI105附近的ROI,接近颌叶的部分，具有较高的底层特征视觉相关性.
B) Two corresponding parts in left-hemisphere and right-hemisphere, in high-level features, those two parts(ROI 24-81 and 117-174) showed continuously higher correlation than other ROIs and features, however, for another experiment object VL, the areas with higher correlation changed. （ROI 24-81 和 117-174对于实验对象DP来说具有较高相关性）
C) One example of sensitivity coefficients further verified the results of low-level features.敏感系数的计算进一步验证了底层特征的结果
D)For VL, there's significant individual difference between it and DP. 对于另一个实验对象VL来说，虽然也存在ROI具有更高的correlation,但是与实验对象DP具有个体差异。

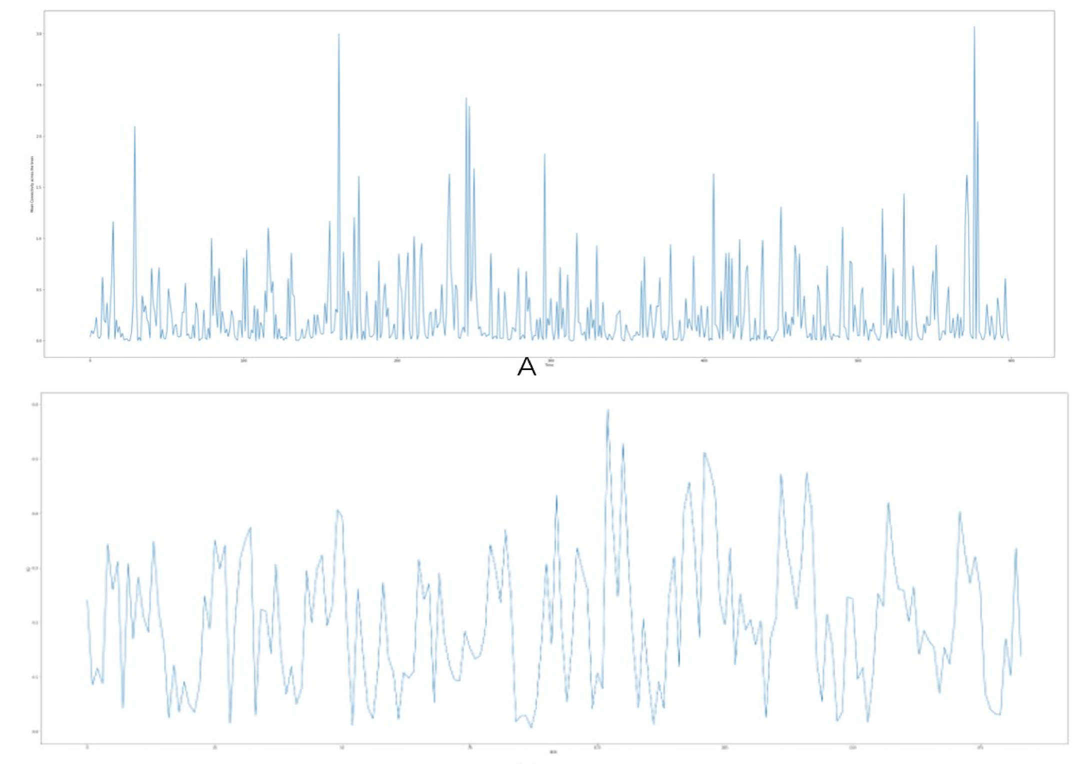

Figure3 Connectivity and Stepwise regression A) One of the visualizations of the connectivity across time B) Variance explanation rate, in total 184 ROIs

A）When connectivity is relatively high, that usually indicates the turn on/off of the videos and the change of the video contents, for example, there's a visible genital appeared on the screen around 3 seconds ago.（当全脑连接程度较高时，往往代表视频开关或者出现了重要特征：比如可见的生殖器）

B) For stepwise regression, almost all of the high-level features showed negative values in the explanation rate, but our low-level features usually showed higher variance explanation rate.
对于逐步回归，几乎所有的高级特征表现出了负值，但是底层特征往往有更高的方差解释率

Conclusion

In conclusion, even though we sill have unfinished parts, we basically discovered a visually sensitive area near cortex, we used both direct convolution and correlation to verify that result.
We also discovered the sensitive areas to some of the high-level features, they have significant individual differences between two research objects.
The connectivity revealed some important features that contribute to the integration of macaque's brain.
In stepwise regression, we can see some of the low-level features contribute a lot to the variance explanation of the BOLD signal. 我们发现了猕猴脑中颌叶附近的视觉敏感区域，并且用了卷积和敏感系数来验证结果。连接性结果揭示了一些对全脑连接产生影响的重要特征。逐步回归中我们发现了一些对BOLD信号产生最重大影响的特征。

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昆山杜克大学 DUKE KUNSHAN UNIVERSITY

Contact
ll338@duke.edu
szechai.kwok@duke.edu