Study on the difference of brain visual information processing between Parkinson's disease patients with hallucinations and healthy people based on EEG

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ABSTRACT

Computer vision is a mode task that uses computer to learn from training data and apply the learned experience to specific task. When patient experiences hallucinations, brain will call the memory stored in the hippocampus and process through specific pattern, and brain visual terminal will receive the image that does not exist in the real world. Patients with Parkinson's disease (PD) for more than 10 years are usually accompanied by hallucinations, which leads to changes in visual information processing and information perception pathway in brain. Electroencephalogram (EEG) is a spontaneous electrophysiological signal of the brain, which can reflect the working mechanism of the brain. In order to explore the changes of brain information perception pathway in PD, we recruited 5 PD patients with hallucinations, 5 healthy elderly and 5 healthy young subjects to participate visual classification experiment. The EEG collected in the experiment was analyzed by spectrum and brain network. The analysis found that the Delta, theta and alpha power of frontal lobe and occipital lobe in PD patients increased, the beta and gamma power decreased, and the brain fell into the internal circulation, the interaction between brain regions decreased. The lack of interaction may be one of the main causes of hallucinations.

Keywords: Hallucinations Parkinson's disease, electroencephalogram, computer vision

1. INTRODUCTION

Computer vision (CV) teaches computers to understand the world through images[1]. Now the research focus of CV has shifted from the traditional hand features to the deep learning. In CV discipline, the deep learning can enable the machine to adaptively learn the data rules of the training set, and then complete specific tasks, such as object recognition, semantic segmentation, three-dimensional reconstruction and other tasks, but performance poor in complex tasks.

Hallucinations are the products of brain lesions. Patients will receive image stored in memory but not in the real world at the visual terminal, and some receive people's sounds at the hearing terminal at the same time. According to the interview of patients' hallucinations, hallucinations are no different from real objects, and occur very fast. It is a high-quality image reconstruction process.

Parkinson is a hallucinatory concurrent neurodegenerative disease. Patients usually have some hallucinations after 10 years of illness. The incidence rate of visual hallucinations is 38%[2], followed by hearing, olfactory and tactile incidence rate of 22%, 16% and 7%[3]. PD leads to structural atrophy of the brain, and then the brain will have functional changes at the same time, resulting in changes in visual and information perception pathways and hallucinations.

EEG records the self generating physiological activities of the brain during work, with high temporal, spatial resolution, low cost and high time resolution. The international EEG Association uses 32 electrode channels to cover the whole brain area through the 10-20 system[4] to locate the electrophysiological activities of each brain area of the subject.

Hallucination is a reconstruction process in which patients obtain images that do not exist in reality through the processing of stored experience by the brain. If the hallucination is regarded as the image reconstruction in the CV, the image information stored by the patient is regarded as the training set, the brain processing is regarded as the processing of the learned information by the machine, and the hallucination is the result of the reconstruction. At present, although the depth network model is relatively mature, it still has some defects, such as high demand for the image quality of training set data, fuzzy generated images, limited types of generated images and so on. Compared with the fast, multi type and clear image

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generation of illusion, it still has a large gap. Studies have shown that EEG has the potential to reconstruct the visual scene[5]. The study of the workflow of hallucination processing in PD may provide new enlightenment for the construction of neural network.

2. PROPOSED METHOD

2.1 Participants and stimuli

Sixty subjects were recruited at Nanjing Naoke hospital. 5 PD patients with hallucinations, with an average age of 67 $\pm$ 1.3, five patients were fully treated that hallucinations were real, 75% patients had at least once interacted with their hallucinations, forming PD group. 5 healthy elderly, with an average age of 65 $\pm$ 1.7, formed the healthy elderly (HE) group. 5 healthy young people, with an average age of 23 $\pm$ 2.4, forming the healthy youth (HY) group.

In the experiment, the subjects were placed in a room with many objects and people. The patients observed the objects or people in the perspective and described them one by one. Each observation and description lasts for 5S, and the time mark trigger is recorded at each observation time. The scene observed from the perspective of the subject is shown in Figure 1. Each subject participated in 3 experiments, and the subjects observed 20 times each time to end the experiment.

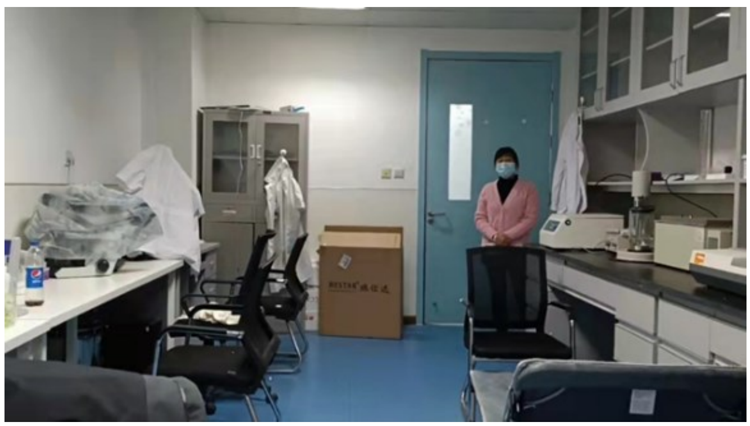


Figure 1. Experimental scenario.

2.2 EEG acquisition and preprocessing

EEG recordings were digitized at 2048 kHz from 64 Ag/AgCl American EGI brain Amplifier electrodes set according to the extended international 10-20 convention. Recordings were processing by were Matlab toolbox eeglab offline. Continuous EEG data were band pass on FIR filter between 0.1 and 200 Hz. Using Nima's standard deviation calculation rule[6] to reject the bad channels. Using ICA toolbox separate EEG component and noise component were removed. According to the trigger recorded in the data, stack and average the data with trigger with 2 seconds as the time window.

2.3 EEG analysis statistical analysis

The EEG frequency distribution is calculated by fast Fourier transform, and each channel is located according to the 10-20 system. Observe the frequency band of each channel: Delta (δ, 0.5-4 Hz), theta (θ, 4-8 Hz), alpha (α, 8-13 Hz), beta (β, 13-30 Hz) and gamma (γ, 30-48 Hz). The calculation of data in independent channels can avoid the problem of inconsistent impedance of different channels.

The normality of EEG data was tested by Shapiro Wilk test, and the nonparametric Mann Whitney U test was used to compare the data that did not obey the normal distribution. Independent sample t-test was used to analyze the spectrum results, which were considered significant when $p < 0.05$.

Take a single channel as the observation node each time, calculate the correlation coefficient between this channel and other channels, and then repeat the calculation method on all channels to obtain the correlation brain network covering the whole brain. Each node of 64 channel EEG equipment can build a set of network diagrams with a scale of 64 (including the channel itself), and 64 diagrams form a brain network with a scale of 64×64. It is considered relevant when the network node value $r > 0.85$.

3. RESULTS

3.1 Spectral and statistical analysis

As shown in Table 1, the average difference of spectrum between PD group and healthy subjects (including elderly and young subjects). The relative increase ↑ represents that the PD group has more enhanced electrode coverage channels than the healthy group, and ↓ represents the opposite situation.

Table 1. Relative increase of EEG frequency band of PD compared with healthy people.

	Relative increase	Proportion of channels	Average increase/decrease ratio
δ	↑	75%	16%
θ	↑	80%	45%
α	↑	55%	10%
β	↓	62%	21%
γ	↓	65%	27%

In the spectrum analysis, the patients with Parkinson's disease δ bands, θ bands and α bands Compared with the healthy group, among which θ the number of high wave power distribution channels accounts for 80%, that is, the average increase of 51 channels is 45%. β and γ bands Compared with the healthy group, the distribution of power decreased, and the proportion of falling channels of two bands data was close, and the average decline was close.

Table 1 shows the average results of whole brain spectrum distribution in each group, and the results of some channels are not significant in the population. Table 2 shows the results of group analysis of the spectrum proportion of whole brain electrode channels using independent sample *t*-test. The significance channel recorded the specific electrode conforming to $p < 0.05$, and the *p*-value recorded the maximum and minimum values of all conforming specific channels.

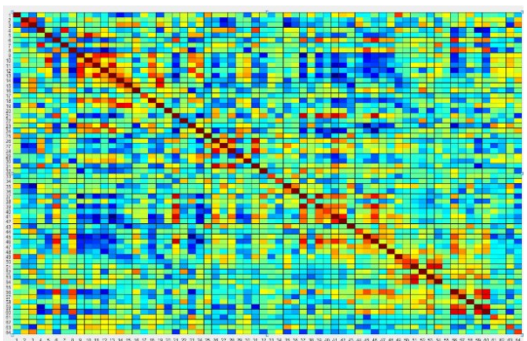
Table 2. Relative power per frequency band in PD, HE and HY group.

	Significance channel	*P*-vlaue PD vs HE	Significance channel	*P*-value PD vs HY
δ	F1, FP1, FP2, FC1, FC2 FC3, FC6, AFZ, AF3, PZ P5, P7, P9, POZ, TP7	$0.017<p<0.05$	F1, F7, FP1, FC2, FC3, PZP8, POZ, PO4, TP7, OZ, O1, O2	$0.027<p<0.05$
θ	F1, FP1, FP2, FC1, FC2 FC3, FC6, AFZ, AF3, C5 CP6, P2, P5, P7, TP7,	$0.005<p<0.05$	F1, F7, FP1, FP2, FC1 FC6, AF4, C1, PZ, P5, P7, POZ, OZ, O1, TP7, TP9	$0.009<p<0.05$
α	FC1, FC3, FC6, AFZ, CZ, C3, T7, T8, P7, P9, O1	$0.034<p<0.05$	FP2, FC1, FC3, FC6, AF4 POZ, TP7, TP9, T7, P3, P7	$0.021<p<0.05$
β	F3, F8, FZ, FC1, FT8, C4C6	$0.029<p<0.05$	F2, FP1, FP2, FC1, FC3 FC6, AF4, PZ, P6, P8, P9 POZ, TP7, OZ, O1, O2	$0.008<p<0.05$
γ	F3, F8, FZ, FCZ, P8, OZ O1	$0.037<p<0.05$	FP2, FC1, FC3, FC6, AF4 PZ, P8, P9, POZ, PO4, OZ O1, O2	$0.009<p<0.05$

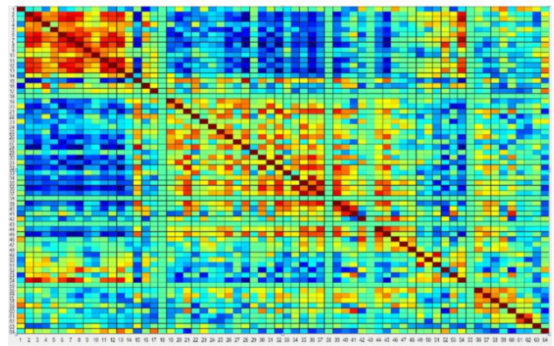
Compared with the HE group, the enhancement of θ bands was the most significant in PD group, followed by δ and α bands, mainly concentrated in the frontal occipital. Compared with the HY group, the enhancement of α bands in PD group was significantly higher than that in δ bands, and the number of electrode amplification channels in temporal lobe increased in α bands. Compared with the HE group, the β and γ bands in PD group have close significance. The decline of β bands distributed in frontal lobe and parietal lobe, and the γ bands distributed in frontal lobe and occipital lobe. Compared with the HY group, β and γ bands increased significantly, and channel number in occipital lobe increased.

3.2 Brain network analysis

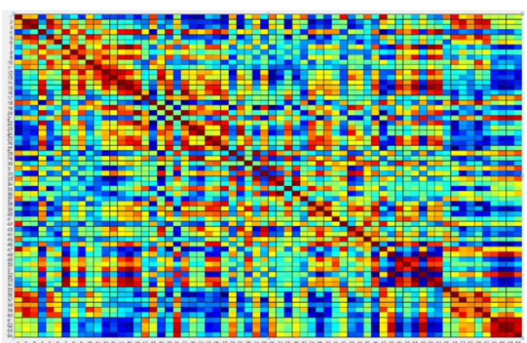
As shown in Table 1, the average difference of whole brain spectrum distribution between PD group and healthy subjects (including elderly subjects and young subjects). The relative increase ↑ represents that the PD group has more enhanced electrode coverage channels than the healthy group, and ↓ represents the opposite situation.



(a) Average brain network in PD group



(b) Average brain network in HE group



(c) Average brain network in HY group

Figure 2. Average brain network of subjects.

Figure 2 is EEG brain network diagram. The value range of network nodes is [- 1,1]. 1 and -1 are marked in red and blue respectively, each node is marked with corresponding spots according to the value. Figure 2a shows the average results of PD group, representing that the positive correlation red coverage is significantly less than that in the HE group in Figure 2b. Figure 2c is the results of the HY group. The number of red coverage is much larger than Figures 2a and 2b, the interaction of brain regions in the visual classification task of young people is stronger than that of the elderly.

When the correlation value of node value r > 0.85, it is considered that the two electrode channels are related in the task. According to the results of brain networks of three groups in Figure 2, record the channel groups with correlation, as shown in Table 3. The channel groups are recorded from large to small in the form of (x, y). The r is value range of all correlation channels.

In Table 2, the channels with strong activity correlation in PD group are mainly concentrated in parietal and occipital lobe, most are autocorrelation in one brain region. Compared with the PD group, the channel correlation of frontal lobe in the

HE group increased, and the cross brain channel from frontal lobe to parietal lobe in the adjacent brain regions increased. Compared with the elderly group, the number of correlation channels in the HY group increased, and the range of cross brain channels increased, and the correlation of some channels in non adjacent brain regions also increased.

Table 3. Correlation channel group.

	PD group	**HE group**	**HY group**
Channel	(OZ, O2) (CP1, CP6) (CP5, P1) (CP1, O2) (FP1, FP2) (CP1, OZ) (CP1, CP2) (AF3, F5) (O2, CP6) (P1, P3) (FT8, F4) (CP5, P3) (C2, FC2)	(P2, P7) (AFZ, AF3) (F2, FC2) (F5, AF3) (C5, CP5) (C2, C6) (F4, FC6) (AFZ, F6) (P7, P9) (CP2, P2) (AFZ, T8) (CP2, P9) (F4, CP2) (FC4, FC6) (O2, PO3) (AF4, F2) (CP1, P9) (F2, FC1) (CP1, CP2) (CP1, POZ) (FC1, FC2) (FC1, AFZ) (O1, OZ) (CP1, O2)	(FC4, C2) (PZ, POZ) (FC1, FC3) (TP8, T8) (C3, C5) (FC3, FC4) (FC1, FC4) (C1, C3) (C1, C5) (FC3, C2) (FC1, C2) (FCZ, FC2) (T7, TP9) (P1, P3) (FP1, T8) (FP2, T8) (AF4, FP2) (FT7, FC3) (FC1, FT7) (P1, PO3) (F6, FT8) (F2, AF4) (FC1, FC2) (FP1, TP8) (F6, F7) (FC2, FC3) (C6, CP6) (C2, FC2) (F5, FT7) (O2, CP6) (P2, PO4) (FP2, TP8) (FZ, P2) (FP1, O2)
r	$0.8564<r<0.9762$	$0.8571<r<0.9883$	$0.8504<r<0.9928$

4. DISCUSSION

In this paper, we set up a visual classification experiment, collected and analyzed the EEG of three groups of subjects. The δ, θ, α bands power of PD group's Compared with the healthy group increased, while β and γ bands decreased. Parkinson's patients are usually accompanied by Alzheimer's disease[7], leading to α and β bands activity reduce, δ and θ bands activity increase, except α bands. It is consistent with the above analysis results. The prefrontal lobe is a channel distribution area with significant spectral changes, which is not closely related to visual work. The abnormal spectral activity of the prefrontal lobe may be related to the generation of hallucinations.

α bands are divided into two categories: one is distributed in the sensorimotor cortex, which is called mμ in some studies, mainly related to motor intention, is blocked when moving. Considering that Parkinson's patients have constant shaking of hands or feet, they may have the intention to stop shaking, resulting in mμ bands increased; The other is distributed in the occipital lobe. Patients with hallucinations not only receive realistic visual information, but also receive visual information caused by hallucinations, which may lead to increased activity in the occipital lobe.

θ bands are mainly positively correlated with the load of working memory, which is caused by the generation of hallucinations, and the enhancement is concentrated near the anterior union of the brain. Recently, many studies have reported the presence of prominent δ bands in the awake state. These studies include Angelman syndrome, epilepsy, behavioral reactivity during propofol anesthesia, postoperative delirium, and the state of dissociation from the environment[8], which is also found in this paper δ bands have an advantage in patients, provides support for above hypothesis.

The decrease of β bands may be due to Alzheimer's disease in PD patients. γ bands will show high amplitude activity when paying attention, which is also used as the carrier of data exchange between brains[9]. The decrease of γ bands means the weakening of neural interaction. This conclusion is consistent with the results of brain network: the interaction of brain network in PD patients in visual work is concentrated in a single brain region and small number of adjacent brain regions. Brain function depends on the cooperation of the whole brain[10, 11]. The brain of PD patients has structural atrophy, which affects the interaction of various brain regions.

5. CONCLUSION

In the analysis of brain network, the correlation channels of PD patients in visual work mainly focus on the autocorrelation in occipital lobe and frontal lobe, the correlation between occipital lobe and parietal lobe, a small number of symmetrical channels, little interaction in different brain regions. The autocorrelation pathways and the channel interaction of different brain regions increased in HE group. The number of relevant channels in the HY group increased significantly, especially the channel interaction in different brain regions, and the interaction length increased at the same time, and the channel interaction across brain regions such as frontal lobe and occipital lobe increased.

The independent work of brain regions may lead to hallucinations. In the research of deep learning, the design of global information interaction and local information self-processing may provide some new ideas for researchers.

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