Blood oxygenation level dependent fmri psychology essay

Functional magnetic resonance (fMRI) is the most widely used and powerful method of understanding the brain function and mapping neuroanatomy of the human brain. The most basic fMRI technique is blood oxygen level dependent (BLOD-fMRI). Paramagnetic deoxyhemoglobin in venous blood is a natural contrast agent for magnetic resonance imaging (MRI). Basic principles and methodological applications of BOLD-MRI as an introduction are presented in this article, and the relationship between neural activation and a magnetic resonance signal change is represented in much detail.

Introduction

Functional magnetic resonance (fMRI) is a widely recognized technique for brain mapping and providing the anatomical information of brain activity. It has been demonstrated that this method bases on the local hemodynamic changes that influence deoxyhemoglobin changes in venous blood. Furthermore, susceptibility changes produced by deoxyhemoglobin changes lead to the changes of MR signal strength. This effect is called blood oxygenation level dependent (BOLD) contract (1). High spatial and temporal resolution brain mapping can be structured by this basic method. Currently, it has become the most powerful study of brain function techniques. Compared with the traditional neuroimaging methods, including positron emission tomography (PET) and intrinsic signal optical reflection imaging, BOLD-fMRI can provide high spatial and temporal resolution sufficiently using internal concentration of oxygenation in human bodies as a natural contrast agent.

Blood oxygen level dependent (BOLD) effect was firstly presented by Ogawa etc in 1990. They found that the magnetic resonance signal reduces when the concentration of oxyhemoglobin decreases. Also, their research showed that the reduction of signal not only occurs in blood, but also outside the blood vessels. Thus, they assert that this effect is caused by the property of magnetic field changes. After that, many researchers performed a large number of theoretical and experimental works to summarize the basis of BOLD-fMRI imaging. When neuron is activated, regional cerebral blood flow and oxygen consumption volume increase, but there are differences between the two increases, which is that the increase in cerebral blood flow is more than the oxygen consumption. Due to this difference, the venous oxygen concentration in active regions is significantly higher than the surrounding tissue and the concentration of deoxyhemoglobin reduces relatively. BOLD contrast has its origin in the fact that when normally diamagnetic oxyhemoglobin gives up its oxygen, the resulting deoxyhemoglobin is paramagnetic (2). Deoxyhemoglobin is a paramagnetic material which can produce local gradient magnetic field in the blood vessels and surroundings. Hence, it has effect on reducing T2. When brain areas are activated, the effect of reducing T2 decreases result from the reduction of deoxyhemoglobin. Compared with the resting state, T2 or T2* is relatively extended in local brain regions. Therefore, the signal is relatively enhanced on the T2 weighting or T2* weighting functional magnetic resonance imaging maps.

Current MRI brain mapping studies all focus on off-on subtraction mode, which is the fMRI signal in active condition minus the signal under control conditions. The signal is extremely weak, and the relative increasing strength is 2%-5% generally. During imaging, the functional image of corresponding brain areas can be obtained if superimposing the high signal in different colors of active area on the high-resolution T1 weighting anatomical maps. This method is called blood oxygen level dependent contrast fMRI due to it depends on the level of oxygen in local blood vessels (1).

This article reviews the basic principles and available methodological information and research on blood oxygen level dependent (BLOD-fMRI). This review begins with some basic principles on BOLD-fMRI. Furthermore, the methods for BOLD-fMRI will be described in detail including block design and event-related design. Also, the results of BOLD-fMRI studies will be presented and the advantages and limitations of the current research will be discussed as well. Finally, the key points and important aspects of the BOLD-fMRI will be summarized as a conclusion.

Materials and Methods

BOLD-fMRI experiment steps include: firstly, make experimental planning and determine the most optimal stimulus or task programs. Secondly, high T1 WL resolution anatomical images and a great number of original images in stimulation and rest states can be obtained by scanning. Lastly, functional active maps should be obtained by experimental data analysis.

Block design bases on cognitive subtraction mode to show the stimulus task in block form. A tropical block design contains two basic tasks which are experimental tasks and control tasks, and the two intervals of blocks appear. Task-related brain activities can be understudied by the comparison of regional cerebral blood oxygen reaction through stimulation and control tasks. It is widely used in locating brain function. It is the early main method to do functional magnetic resonance imaging experiments. The advantages are simple and easy to perform tasks. However, the drawback is that the BOLD signal changes larger result in long stimulation time and the high rate of oxygen reaction.

In blocked designs, regardless of stimulus presentation or task performance interdigitated with rest, observing the relationship of the time course of BOLD response to activation paradigm is possible (3). Also, more than one image can be obtained during every experimental and rest period. The signal time course should be assumed to be activated, and it can be tested. A simple example is presented in Figure 1(a). Firstly, switch on and off the visual stimulation (black and green) quickly for 10 times. It is shown that the time course of pixels follows the stimulation paradigm. However, the difference between the stimulation and time course is quite obviously ($p <. 0001$). Figure 1(b) shows a relative complicated case. The experimental condition is resting, moving the left hand, resting, and then moving both hands. This comparison is based on statistical tests of hypotheses which can be applied to this experiment. For left hand and both hand movements, the data presents that the result is different form most subjects moving their right hands. Though the medical motor areas and the primary motor cortex are activated, the medical motor areas are more possible to be activated when the dominant left hand is being moved than when the dominant is being moved. In summary, the time course in block design shows that the direction and magnitude of signal change is determined by experimental paradigm.

Buckner proposed a new experimental design called event-related design or single-event design recently. For this method, the smallest unit is single stimulus or event that can be controlled rather than blocks. BOLD signal induced by single event is usually weak, thus BOLD signal superposition induced by multiple events are applying in practical applications. This recent design is intended to overcome the drawbacks of block designs (3). To begin with, event-related experimental design can reduce the weary effect during the psychological research better. Furthermore, it can be used to reduce the signal interference caused by head movement, and it also can be used in some cognitive tasks when slight head movement cannot be avoided such as swallowing and talking loudly, and the results are significant. Lastly, it can be used for number of experiments cannot apply block design and it also present a more accurate description of BOLD signal. Nevertheless, it has some disadvantages as well. For instance, some certain experiments cannot adapt to this method such as acupuncture experiments. Subjects' attention will be reduced due to a longer stimulus interval time. Also, the data analysis methods for envent-related design are not ripe yet.

In essence, block design is a special case of event-related design. In the event-related design, it becomes block design when reducing the stimulus interval of several tasks to zero. Hence, event-related design is more general and universal. In event-related design and block design, the relationship of the time course is different.

Results

The time course in block design shows that the direction and magnitude of signal change is determined by experimental paradigm. The magnitude of activation can be calculated by counting the number of pixels. According to the initial conditions, time course may be positive or negative. Also, time course demonstrated more aspects of BOLD signal. Therefore, the time course of block design provides a basis for judging the functional neuroanatomy. Even, some inferences have been made that the temporal changes in the BOLD signal unfold in time. However, this design has some limitations. In a block design, many accurate data may be shut out in any task during the protracted period of time. The information of temporal changes are not always abstracted, thus many studies assume that the temporal resolution in fMRI is limited.

The resolution is determined by temporal distance between ages. The temporal resolution will be better if the temporal distance is shorter. There are so many solutions to increase resolution, but the simplest is to limit the slices. It takes so long time to map the whole brain result in the complicated networks. Obviously, time will be shorter if the region of interest can be reduced to a few slices.

Event-related researches also undergo some criticisms as block designs. When many trials have been done to produce a time course, later trials may be different from early trials. Many time-resolved designs also haven begun to detect the differences. The results presented that different subjects have different hemodynamic response in different areas of the brain.

As mentioned above, BOLD activation comes from the blood flow accompanies neuronal activity, and the signal time course may move in positive or negative direction in a special condition. BOLD images provide a spatial resolution which is more advantageous than other methods such as PET or EEGs. The signal needs to be detected in noise result from the small pixels. As shown in Figure 2, it provided the space for believing the activation. However, using the spatial resolution, the reliability of fMRI and the stability of images are unconvinced now.

Discussion

The technology of functional brain mapping by MRI is developing significantly. Although the temporal solution relies on similar principle, which is hemodynamic responses to neural activation as PET do, but the spatial resolution is higher, and high resolution images can be obtained (1). Also, the MRI method has a slow time resolution though it is the same order as hemodynamic response time. We also found that the changes in blood oxygenation can be detected through BOLD-contrast MRI of brain. Contrast is determined by the blood flow and requirement of oxygen result in it depends on blood oxygenation (2).

Some new MRI methods are being studied to alter positron emission tomography (PET) in the field of regional blood flow research. PET depends on tracer methods to measure different physiological quantities. BOLD contrast provides a similar and complementary method to PET in the research of regional brain activity. BLOD contrast depends on a natural contrast agent and the image can be stimulated with good time resolution. What is more, transient changes in blood oxygenation can be measured too.

From the introduction to the present, fMRI has become an indispensable research tool in the neuroscience field. However, is also has some drawbacks such as its accuracy has not been clarified completely, particularly for its spatial specificity as the large veins can produce BLOD response and these veins are away from the sites of neural activity. According to the results, fMRI is in the control of large blood. Effects of large blood vessels relate to the flow effects, but both effects are not we need. In many cases, the real spatial positions related to the power of blood cannot be determined result in the micro changes. In addition, fMRI data may be fluctuated by physiological noise and the movement of subjects.

Conclusion

BOLD fMRI is really the most widely used and powerful functional brain imaging technique. It has widespread influence on neuroimaging and clinical practice. The brain functional image is based on changes in local oxygenation and activation. The time courses of blocked design can be used for statistical inferences of the networks in complex psychological processes. Time-resolved and event-related designs can be used for number of experiments cannot apply block design and it also present a more accurate description of BOLD signal.

In this day and age, fMRI is an important approach to study the brain function in a non-intrusive type. Further research, improvement and innovation on the methodology will make it obtain widely development in the application field.