A Study on the Synchronization of the Brains of Students in Video Teaching

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Abstract. Previous papers have explored the learning effect in video-based teaching based on the synchronization of brain activities between learners. For example, researchers used the synchronization of brain activities between learners investigated the effectiveness of different video-based teaching methods. However, most of the previous articles focused on the teaching videos of declarative knowledge. Based on the synchronization of brain activity, this paper studies the learning of college students when they learn the teaching video of procedural knowledge. Ten college students were randomly selected as subjects, and a Neuroscan equipment was used to record the Electroencephalogram (EEG) data of subjects when they watching the teaching videos. Then, the synchronicity between the subjects of each electrode was analyzed. We found the higher synchronization of brain activities in the frontal lobe and the parietal lobe between subjects. In summary, compared with previous studies, we focus on the teaching videos of procedural knowledge, and our results showed that the frontal lobe and parietal lobe synchronization between subjects during the video-based learning. The results of our study are consistent with previous studies on video-based learning, which found higher synchronization in the frontal lobe. Moreover, our findings indicate the higher synchronization in the parietal lobe during procedural knowledge learning.

Keywords: Declarative knowledge, video-based learning, synchronization, brain activation

1 Introduction

1.1 Video-based Learning

With the rapid progress of information technology, video-based teaching, a modern educational form, has been widely used in education. It breaks through the limitations of traditional classrooms and provides students with a more flexible and convenient way of learning. Nevertheless, there are some challenges in video-based teaching[1], for example, students are easily distracted due to the lack of real-time interaction during video-based teaching. Therefore, how to optimize video-based teaching strategies has become a key issue in current educational research[2]. Although some papers have

D. Hu et al. (eds.), *Proceedings of the 2024 5th International Conference on Modern Education and Information Management (ICMEIM 2024)*, Atlantis Highlights in Social Sciences, Education and Humanities 29,
https://doi.org/10.2991/978-94-6463-568-3_65

discussed the effectiveness in video-based learning, however, the learning of students when they watch the teaching video is still unclear.

In addition, the previous researches on video-based learning mainly focused on declarative knowledge. That is to say, the content of the teaching video is mainly about the description of what, where and who. For example, knowing that "the capital of China is Beijing" is declarative knowledge. Declarative knowledge includes facts, definitions, rules, principles and so on. It focuses on the description and understanding of things, and mainly used to express something, someone, somewhere. By accumulating declarative knowledge, students can gradually build up their own knowledge system and provide solid support for subsequent learning. As we known, declarative knowledge is the basis for learning other types of knowledge, such as procedural knowledge. It provides the necessary information and context to help students understand more complex concepts and skills.

We know that in addition to declarative knowledge, there is also procedural knowledge, that is, knowledge about "how to do". For example, chemical experiment, paper-cut and flower arrangement are procedural knowledge. There are different characteristics and application scenarios of declarative knowledge and procedural knowledge. Both of declarative knowledge and procedural knowledge are very important in learning for students. Procedural knowledge focuses on the steps and skills[3]. It emphasizes practical operation and practical ability. Students can master specific operation steps and methods through learning, so as to improve their practical ability. When facing a problem, students need to apply the procedural knowledge they have learned to find a solution through a series of operational steps. This process exercises students' problem-solving skills and enables them to deal with various challenges more effectively.

At present, there is little research on the teaching video of procedural knowledge. However, many teachers will teach the procedural knowledge based on video. And many students also use videos to learn procedural knowledge [4]. Therefore, this paper uses the teaching video of procedural knowledge to study.

1.2 Inter-subject Synchronization

With the development of electroencephalogram (EEG), functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS) and other neuroscience technologies, more and more researchers begin to use these tools to investigate the learning and teaching. By simulating daily teaching in a controlled experimental environment, researchers can directly record the brain activity of teachers and students.

How to evaluate students' learning effect has always been a hot topic in pedagogy and psychology. In the field of video-based learning, some studies have conducted research based on brain activity[5]. Precious study recorded the brain activities of teachers and students in face-to-face and video-based teaching environments to evaluate the learning effect[6]. They used functional near infrared spectroscopy (fNIRS) to record the changes of brain activity of teachers and students in different teaching designed, and the synchronization of brain activity between the student and the teacher was calculated. On the one hand, the results of this study provide more sufficient evidence for the synchronization of brain activity as a neural marker of teacher-student teaching interaction[7]. On the other hand, it also suggests the possibility of the synchronization of brain activity as an objective neural indicator for investigating teaching quality[8]. And, researchers recorded the brain activity of teachers and students at the same time.

It worth note that, researchers also sued inter-subject synchronization to investigate what kind of teaching video do students like and why do some teaching video attract students more. For example, previous paper used functional near-infrared spectroscopy (fNIRS) to record the brain activity of the violinist, while recording the video of violin performance[9]. Then the students watched the video of violin performance, and their brain activity also be recorded by using functional near-infrared spectroscopy (fNIRS). The researchers assessed the students' preference for these videos and calculated the synchronization between the students and the violinist. Their results give the suggestion about how should teachers present the teaching video to attract the students.

Moreover, researchers also used electroencephalogram (EEG) to investigate the brain activity synchronization between subjects[10]. For example, previous paper shows that the degree of synchronization of students' brain activity can predict students' participation in learning by using electroencephalogram (EEG) [11]. The study used electroencephalography (EEG), which provides a noninvasive way to measure the brain's electrical activity [12]. Electrodes are placed on the scalp to capture the voltage changes generated by the neurons and the currents around them. This technology can monitor the activity of the brain in real time. By analyzing signals, electroencephalogram (EEG) can provide important information about individual's cognitive state, emotion and attention. Therefore, in our study, to investigate the video-based learning of procedural knowledge, we employed electroencephalogram (EEG) to investigate the brain activity synchronization between students.

2 Methods

2.1 Subjects

Ten college students aged 18 to 22 years old were recruited from a university, including 3 male students and 7 female. All subjects were right handed. None of the subjects have learning experience related to the teaching video. All the subjects signed the informed consent form before the experiment and were paid for their time after the experiment.

2.2 Teaching Videos

In this study, the content of the course "Handmade Classroom", a national quality course on the Chinese Massive Open Online Courses website was selected. As shown in Figure 1, five paper-cutting teaching videos in the first lecture were used as five experimental materials. The duration of each teaching video is about 10 minutes, and the video content includes paper-cutting demonstration.

Fig. 1. Teaching video.

2.3 Experimental Design

The experimental environment is a quiet room. During the experiment, visual stimuli were presented via a monitor (60 Hz refresh rate, 1280 ×1020 pixel resolution) using E-prime. Before the experiment, a red fixation was shown in the center of the screen. Subjects were told when they were ready for the experiment, can press any key to start the experiment. During the experiment, five different paper-cutting teaching videos were presented in turn, with a two-minute break between each teaching video. Subjects were asked to learn carefully, and reduce head shaking and frequent blinking. After all the teaching videos are played, the subjects will need to complete a test paper and a paper-cutting task to make sure every subject learn carefully. In this study, we used the Neuroscan 128-channel electroencephalography (EEG) equipment to record brain activity. The resistance of each electroencephalography (EEG) electrode was lower than 10 kΩ. The filter band-pass was 0.01-100 Hz and the sampling frequency was 1000 Hz.

2.4 Data Analysis

After data collection, EEGlab was used for data pre-processing. A high-pass filter is used to eliminate unwanted frequency components, preserving the 0.1-50Hz band. In our study, to calculate the inter-subject synchronization, the sampling rate is reduced from 1000 Hz to 100 Hz. We correct for baseline drifting in electroencephalography (EEG) signals to ensure that all data have the same baseline level. This paper uses Matlab to analyze the correlation of electroencephalography (EEG) signals between different channels of each subject.

According to previous study, to investigate inter-subject synchronization, Pearson correlation was performed on the electroencephalography (EEG) signals of each channel across the subjects. First of all, for each teaching video, we get the time courses (signals) of each electroencephalography (EEG) channel for each subject. Secondly, for each teaching video, we leave one subject out, and calculate the average time courses of the other nine subjects for each channel, namely averaged time courses. We did this analysis for each subject, in other words, we did leave-one-subject-out analysis ten times. Thirdly, for each subject, we calculate the Pearson correlation coefficient of the time courses between this subject and the averaged time courses for each channel. Based on this analysis, we obtained the inter-subject synchronization for each subject. And then, for each channel, we got ten Pearson correlation coefficients (ten subjects) for each teaching video. Finally, for each teaching video, for each channel, we calculate the mean of the ten Pearson correlation coefficients across subjects. In this study, we focus on the electroencephalography (EEG) channels with the highest Pearson correlation coefficients for each teaching video to investigate the inter-subject synchronization.

3 Results

This paper used Pearson correlation to investigate the synchronization between subjects during paper-cutting learning. For different teaching video, we got the averaged Pearson correlation coefficient of each channel. The 10 electrode channels with the highest Pearson correlation coefficient and the corresponding brain regions were as following figure.

As shown in Figure 2, for teaching video 1, the ten electroencephalography (EEG) channels with highest Pearson correlation coefficients were FT8, F7, F8, FT7, FC5, C5, FC6, F4 and FC3. And the corresponding brain regions were almost in the frontal lobe. As shown in the figure, for teaching video 2, the ten electroencephalography (EEG) channels with highest Pearson correlation coefficients were FC1, C2, PZ, F8, TP7, FP2, PCZ, FT8 and FC1. And the corresponding brain regions were almost in the frontal lobe, and some in the parietal lobe. As shown in the figure, for teaching video 3, the ten electroencephalography (EEG) channels with highest Pearson correlation coefficients were F7, FC5, FT7, T7, FC6, F4, F5, F3 and F7. And the corresponding brain regions were almost in the frontal lobe. As shown in the figure, for teaching video 4, the ten electroencephalography (EEG) channels with highest Pearson correlation coefficients were AF3, P4, OZ, P2, PO4, AF4, FC1, FT8 and AF3. And the corresponding brain regions were almost in the frontal lobe. As shown in the figure, for teaching video 5, the ten electroencephalography (EEG) channels with highest Pearson correlation coefficients were FC6, CZ, CP4, TP7, C5, PZ, T7, P2, F5 and FC5. And the corresponding brain regions were almost in the frontal lobe and the parietal lobe.

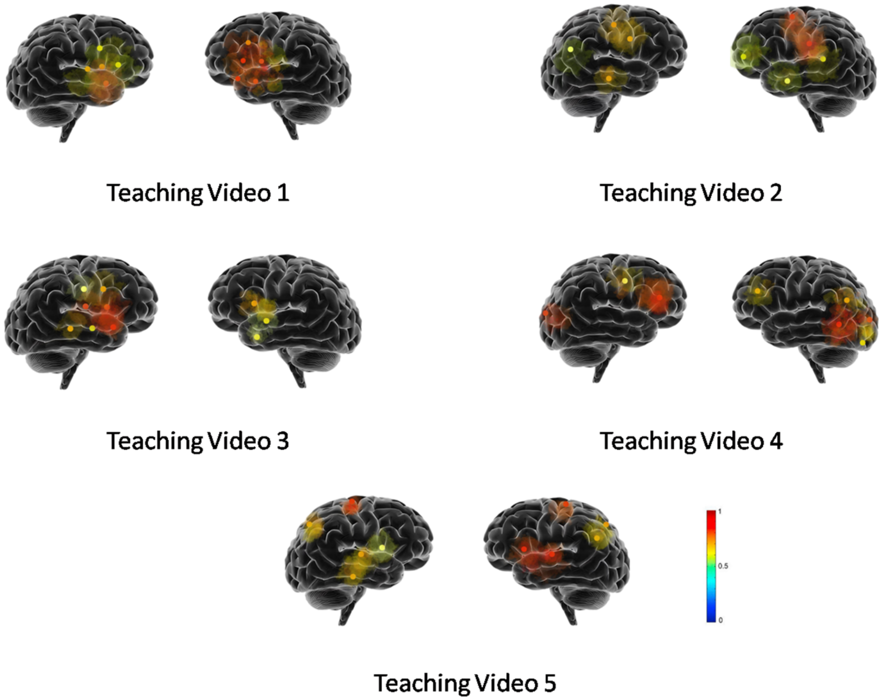

Fig. 2. The ten highest Pearson correlations between subjects for each teaching video.

4 Conclusion

Our study explores the synchronization of brain activities between students in video-based learning of procedural knowledge. In this study, five different paper-cutting videos were employed, and the results showed electroencephalography (EEG) channels and related brain regions with higher synchronization of brain activity between students. Our results suggested most of the electroencephalography (EEG) channels and related brain regions were in the frontal lobe.

As we known, several brain regions in the frontal lobe are involved in higher cognitive functions such as working memory and attentional control. Moreover, our results are consisted with previous studies on learning [6, 13,14]. For example, previous study on music learning found the brain activity of inferior frontal cortices was synchronized between the teacher and student [13]. In a song-learning task, researchers also found when the inferior frontal cortices were stimulated by using the transcranial alternating current stimulators (tACS), the learning performance of learners was increased [14]. Similarly, our results also indicate the higher synchronization of brain activity between students in the frontal lobe is important for video-based learning of paper-cutting.

Moreover, we found there are also some other electroencephalography (EEG) channels and related brain regions in the parietal lobe. For example, the TP7 is located in the posterior parietal cortex. The parietal lobe is involved in spatial processing and visual attention[15,16]. For example, previous paper found the brain activity in the inferior parietal lobule encodes the information of spatial distance[15]. The parietal lobe is involved in the representation and manipulation of spatial information. This includes tasks such as understanding and navigating through space, perceiving the relative positions of objects, and visualizing objects in three-dimensional space. The higher synchronization in TP7 indicated that students show better coordination and interaction in processing spatial tasks (paper-cutting). Interestingly, the results of our study are consistent with previous studies on spatial processing, since the paper-cutting task related to spatial processing. Moreover, the parietal lobe is involved in the planning and execution of complex motor skills. It integrates sensory information from various body parts, such as touch and vision, to create a comprehensive representation of the body in space. This information is crucial for coordinating and executing precise movements. For instance, when you reach for an object, the parietal lobe helps you to perceive the position of your hand relative to the object, and to adjust your movement accordingly. In our study, the higher synchronization in the parietal lobe suggested when subjects watching the paper-cutting videos, their parietal lobe help them to learn the paper-cutting skills.

Our finding supports the use of electroencephalography (EEG) technology to investigate the synchronization of brain electrical activity to evaluate the effectiveness of video teaching[17]. In this study, we found the higher inter-subjects synchronization in the frontal and parietal lobes during the video-based learning of paper-cutting. As we known, in the field of education, teachers can use inter-brain synchronization to assess students' learning status and engagement, so as to adjust teaching strategies and methods. The reason is the synchronization changes between these brain regions can reflect the interaction relationship and cooperation degree between students. In other words, the higher inter-subjects synchronization may indicate the better instructional designs and learning effects.

Based on our results, we suggest the educators used the inter-subjects synchronization of the frontal and parietal lobes as the neurological indicators for video learning of procedural knowledge. For example, the educators can design different videos of procedural knowledge learning, and compared the inter-subjects synchronization of the frontal and parietal lobes for different videos. The better design of teaching videos may lead to the higher inter-subjects synchronization of the frontal and parietal lobes. Therefore, based on the synchronization found in the study, we can optimize the teaching methods and strategies in the video-based teaching in the future.

However, there are still some limitations in this study. First of all, the sample size of our study is small. Thus we will increase the sample size in the future. More students with different backgrounds will participate in this study. In the future, based on the methods used in this study, we will continue focus on the paper-cutting learning. Secondly, we investigate the video-based learning in the laboratory environment, not in a real learning environment as most previous studies. But some electroencephalography (EEG) studies on learning have done experiments in the real classroom environment [18]. For example, researchers used the Low-Cost Portable Electroencephalography (EEG) to make a breakthrough on experimental design[19]. Thirdly, the current researches on video-based learning mainly ignore students' interest and motivation. However, students' interests and motivations may have an impact on their electroencephalography (EEG) synchronization and learning outcomes[20]. In the future, it is very important to pay attention to students' interest and motivation in video-based studying.

Acknowledgements

This study was supported by Philosophy and Social Science Research in Colleges and Universities of Jiangsu Province (grant number 2021SJA0471).

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