A Study of Attention Difference between Traditional and Digital learning Materials Using Brainwave Measuring Devices

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Abstract: Attention is an important factor of learning because a focused learner shows better learning efficiency. Attention also reflects the teaching quality of a teacher, so if a teacher understands the attention level of a learner, he can improve the teaching method to enhance attention and interest in the course. With the development of computer and internet technology, teaching materials have also been developed in different ways. In addition to traditional printed materials, various digital materials are now options for learners. However, the type of teaching material used to grab the attention of learners should also be considered. Therefore, this study used subject of Algorithm as an example. The same topics were presented by both traditional printed materials and digital materials. Electroencephalogram (EEG) was used while the learners were reviewing, and the collected data were analyzed. The results showed the attention levels to traditional printed materials and digital materials and can be used as a reference for teachers.

Keywords: Attention, Dual-coding Theory, E-Learning

1. Introduction

Learning is a necessity in life. However, depending on the personality, interests and values of different learners, they will have different ways of absorbing knowledge to learn. Therefore, understanding the motivation of the learners and providing appropriate teaching methods to stimulate their desire to learn are vital. Research by Petri showed that motivation induces and sustains learning and leads the learner to pursue learning objectives. Stronger motivation also causes better performance (Petri, H.L., 1986). Furthermore, Keller proposed the ARCS model of motivation, which states that strengthening motivation requires four key elements that form a mutually dependent loop. The ARCS model consists of Attention, Relevance, Confidence and Satisfaction. Attention refers to the initial stimulation to the learner, making the learner realize the interesting part of learning; relevance refers to making the learner realize that he/she needs instruction; confidence refers to learners thinking that they are capable of learning certain knowledge; and satisfaction refers to the intrinsic reinforcement and extrinsic rewards after spending efforts to master certain knowledge (Keller, J. M., 1983)(Keller, J. M., 1996).

In the ARCS model of motivation, learning is initiated by stimulating the learners' attention, thus making attention level very important. Hans Berger found that a normal human brain emits four types of frequency, of which theβwave is most associated with attention (Berger, H., 1929). In the modern age of technological development, brainwave measuring equipment has evolved from large and heavy equipment using vacuum tube technology to advanced equipment that bears similarity to a set of headphones in terms of size and usage. Therefore, this study aims to measure learning attention when studying different teaching materials using EEG.

2. Literature Review

2.1 Dual-Coding Theory

In the concept of dual-coding theory, Paivio believed that in the cognitive process, information is coded in two different ways: the Verbal System that controls language and words and the Nonverbal System that controls visuals sounds, etc. (Paivio, A.,1986).

The two systems are connected in three ways, which are Representational Connection, Referential Connection and Associative Connection (Figure 1).

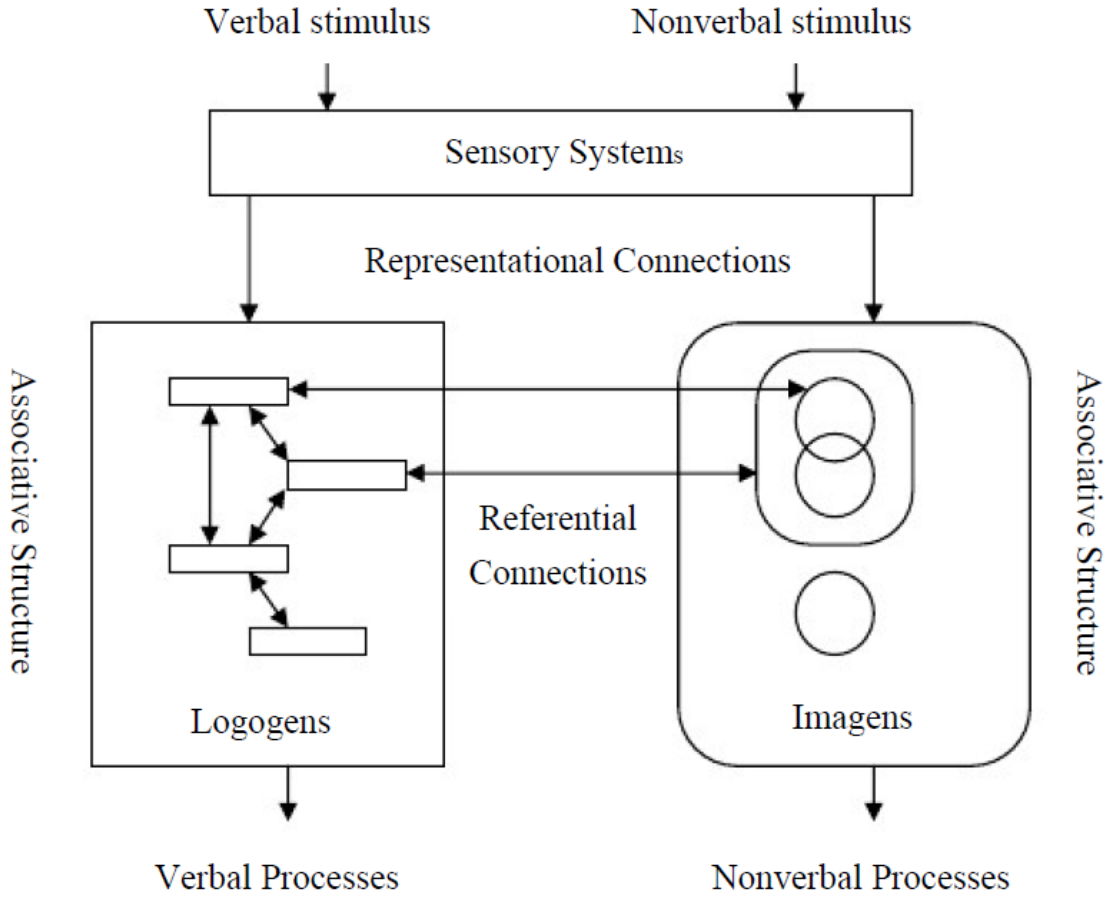

Figure 1. Dual-coding theory (Paivio, A.,1986)

The Representational Connection refers to the initial characterized action when the individual receives the stimulus. The Referential Connection refers to the connection between the verbal system and non-verbal system to form the association. The Associative Connection refers to the connections made between elements that share the same characteristics within the same system (Paivio, A.,1986).

The dual-coding theory has been proven in many studies. Presentations in words and pictures are much more effective than learning simply by words. One study (Mayer, R. E. & Anderson, R. B., 1992) that used digital materials made by computers found that the learning performance is much better in the presentation of both words and pictures compared to only words. In another study (Mayer, R. E. & Sims, K., 1994), digital materials was used for a multimedia teaching experiment, the results of which share common ground with the dual-coding theory.

2.2 Learning Attention

Since 1970, attention has been a popular research topic in the field of psychology. Attention refers to the inner response to focus and concentrate on an important issue to quicken cognitive process or ensure accuracy (James, W., 1983). When the entire mind is put into a certain object or issue, this is known as attention (Solso, R. L., 1995). In cognitive psychology, learning is considered a complex cognitive process when the learner actively pays attention, senses, understands, and networks (Jensen, A. R., 1998). When a learner shows ambition to learn, that enhanced focus also positively affects learning performance (Corno, L., 1993).

Because attention affects learning performance, using such methods as self-monitoring to train the attention level of the learner can assist underperforming learners and enhance their learning outcomes (Steinmayr, R., Ziegler, M. & Tra¨uble, B., 2010)(Purdie, Hattie, & Carroll, 2002). Furthermore, attention level can be used as a reference for learning performance. The rapid development of the internet has led to the possibility of online self-learning, an important factor of which is self-regulation, which affects learning performance. Therefore, self-regulated learning has become very important. Researchers have also incorporated attention evaluation into self-regulated learning, leading to the formation of the attention-based, self-regulated learning mechanism (ASRLM). By using EGG measurement, (Sturm, W., 1996) categorized attention into Alertness, Selective Attention, Sustained Attention, and Divided Attention. Of these, sustained attention was compared among participants with and without the wearable attention level measuring equipment. Research has shown that learners who wore the equipment have a better understanding than those who did not wear the equipment (Chen, C. M. & Huang, S. H., 2013)(Sturm, W., 1996). Furthermore, researchers have also investigated how attention level affected learning by different types of teaching materials. This study aims to compare teaching materials of the same content in traditional print format versus digital format and investigate the difference in attention levels (Chen, C. M. & Wu, C. H., 2015).

2.3 Application of Brainwaves

Brainwaves were first discovered by Richard Caton after detecting a low level of electrical impulses on the cerebral cortex of animals. This initiated the field of brainwave research. The official name “brainwaves” was coined by Hans Berger and Richard Caton. The measurement of electrical signals of the human brain is called Electroencephalogram (EEG). Based on the different frequencies of brainwaves, Hans Berger found theα, β, δ and θ waves and that out of the four, theβwave is most closely associated with attention (Berger, H., 1929). Furthermore, the two scholars later found that when a change occurs in a certain region of the brain caused by the change in brainwave, it can be measured and is called Magnetoencephalography (MEG). Both EEG and MEG are commonly used in medical fields (Caton, R., 1875)(L. F. Haas)(Tudor, M., Tudor, L., Tudor, K. I. & Hans Berger).

Application of brainwaves in medicine has developed into non-invasive monitoring and analysis of the brain, including technology such as the Magnetoencephalography (MEG), Single Photon Emission Tomography (SPECT), Transcranial Magnetic Stimulation (TMS), and Optical Imaging. Furthermore, due to the constant improvement of technology in recent years, brainwaves can also be applied to teaching research. In some studies (Chen, C. M. & Wu, C. H., 2015)(Sun, J. C. Y., 2014), brainwave data were used as a tool to measure learning effectiveness.

Two common methods involving brainwaves are used to measure attention. The first method asks the subject to complete a questionnaire regarding attention after the test, but the subjects are aware of the purpose of the questionnaire and thus may provide inaccurate answers. The second method collects physiological data using equipment that measure physiological signals and then analyzes the data statistically. This method overcomes the limitation of subjective perception that exists in the first method. This study used the second method to measure learning attention with EEG.

3. Research method

3.1 Hypotheses

- Hypothesis 1: The attention level is higher when studying digital materials compared to traditional printed materials.
- Hypothesis 2: When doing the Lightning Round, the learners are more focused.
- Hypothesis 3: When learners empty their mind, it affects their attention level.
- Hypothesis 4: When watching an interesting video, the level of attention is the highest.

3.2 Subjects

The subjects were bachelor students in their 3rd or 4th year and postgraduate students in their 1st or 2nd year in the Department of Informational Engineering in the School of Engineering of a technology university.

3.3 Equipment

This study used NeuroSky EEG to measuring the level of attention. As shown in Figure 2, the equipment collects physiological signals from the brain via special sensor electrodes and transfers the signals to the ThinkGear chip to filter and enhance the useful information. The equipment then uses a patented algorithm to interpret wavelengths of the brainwave and analyzes the frequency of each wave. Computers and mobile phones are used to record the data and discover relevant information using statistics (Buduan, P. J. L., 2012).

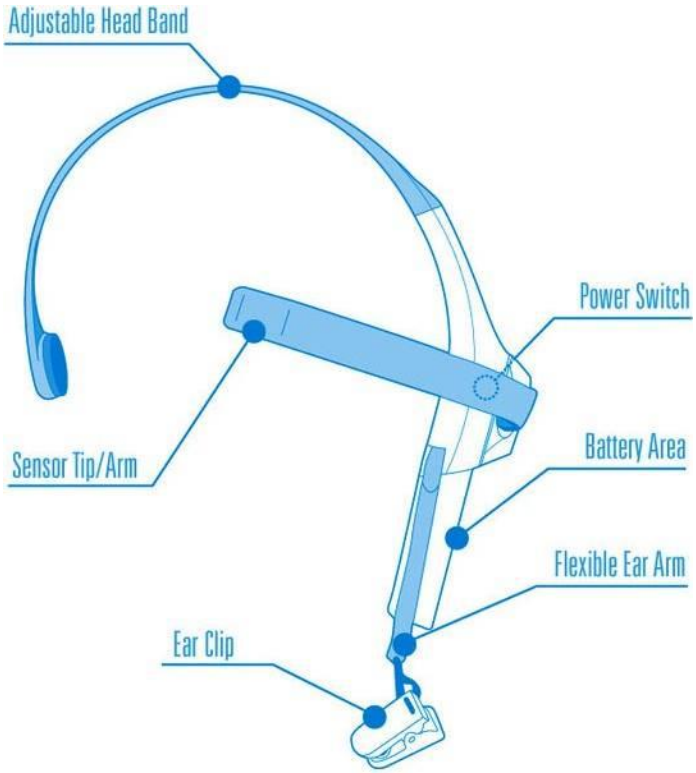

Figure 2. NeuroSky MindWave (Buduan, P. J. L., 2012)

3.4 Teaching Material Design

The teaching material was based on "Foundations of Algorithms Using C++ Pseudocode" 3rd edition by Richard E. Neapolitan and Kumarss Naimipour. The design materials adapted Mayer's cognitive

theory of multimedia learning and was evaluated by three internal or external experts of the field. The experts approved the design's content validity, which was then used in the test.

3.5 Experimental Design

This is a quasi-experimental study using algorithm courses. The content of the traditional printed materials and digital materials is identical. EEG was used when the learners were reviewing the material. The learners were evenly distributed to the control and treatment groups based on their past scores of algorithm tests. The content of the review consisted of Prim's and Kruskal's algorithms. The review time was based on the situation. Figure 3 shows the experimental design.

As for "Lightning Round", the students are asked some questions that are easy but need a little attention, such as 2+3=? For "empty their mind", the students are asked to stay in any condition to totally relax, such as closing their eyes. For "watching interesting video", the students are asked to watch the videos they are interested in.

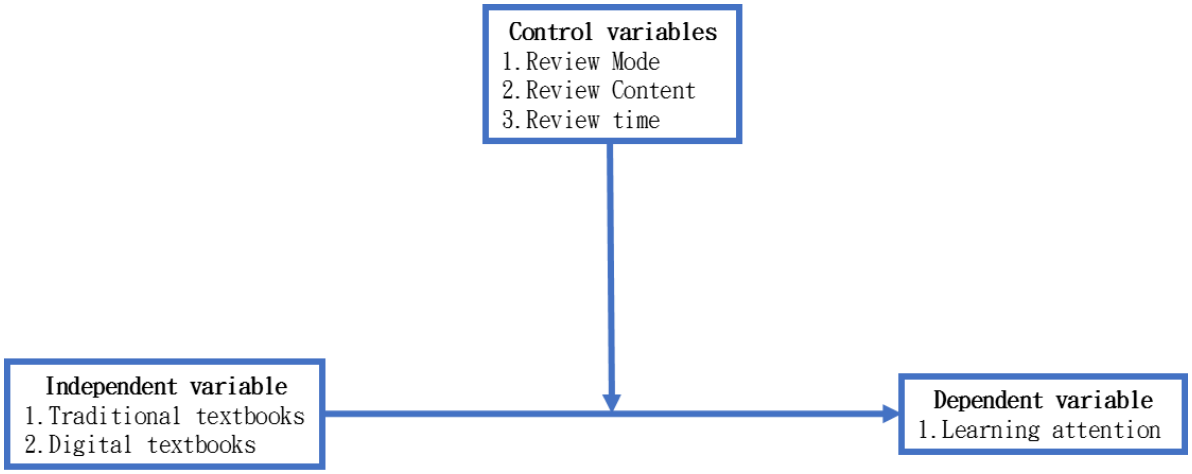

Figure 3. The experimental design

3.6 Experimental Procedure

The experimental procedure is divided into the following six stages:

Stage 1: Before the test starts, the experimental procedure was explained to the participants to minimize uncertainty. Pre-test questions, were given to assess learning performance. Participants were given 10 minutes for the pre-test and have to record the time they took to complete it. The questionnaire can be completed afterwards. A 5-minute break was given.

Stage 2: Teaching materials in the print and digital format were designed to contain a similar level of difficulty for Prim's and Kruskal's algorithms. Four teaching materials were used: digital material on Prim's algorithm, print material on Prim's algorithm, digital material on Kruskal's algorithm, and print material on Kruskal's algorithm. The test was continued when the treatment group was randomly given the digital material on either Prim's or Kruskal's algorithm to assess attention level and relaxation level. The control group was given the printed material on the other unchosen algorithm to assess the same factors. The test took five minutes, and a break of exactly 5 minutes was given with no early continuation allowed.

Stage 3: The participants were then asked to label the attention ladder diagram based on their impressions made in Stage 2. The post-test was then conducted to investigate learning performance. Early submission of the test paper was not permitted for this 5-minute test.

Stage 4: After the 5-minute break, the treatment group repeated the process of the control group and vice versa for the control group. The process was video-recorded. An attention ladder diagram was given to each participant to label, followed by another post-test to investigate learning performance. Early submission of the test paper was not permitted for this 5-minute test.

Stage 5: The participants were asked to complete a questionnaire regarding their own level of attention. The questionnaire should take approximately 3 minutes.

Stage 6: The participants were asked to wear EEG and watch an interesting video, do the Lightning Round, and close his/her eyes and empty his/her mind; each activity took one minute. This stage is performed to determine if the three test curves match the previous test curves.

4. Results

Due to the number of experimental EGG and complications of the experimental procedure, only four participants have completed the test. Two participants studied the traditional print material followed by the digital material. The results are shown in Figure 4. The y-axis represents the average attention during 5 minutes, and the x-axis represents the participants. Kruskal_T1 means that the participants studied the traditional print material on Kruskal's algorithm first. Prim_D2 means that the participants studied the digital material on Prim's algorithm afterward. The other two participants studied the digital material followed by the traditional print material. The results are shown in Figure 5. The y-axis represents the average attention during 5 minutes, and the x-axis represents the participants. Prim_D1 means that the participants studied the digital material on Prim's algorithm first. Kruskal_T2 means that the participants studied the traditional print material on Kruskal's algorithm afterward.

First, we tested Hypothesis 1: The attention level is higher when studying digital materials compared to traditional printed materials. In our four subjects, only one person showed opposite results to Hypothesis 1. A possible reason may be that the person prefers reading print, causing a higher level of attention when studying traditional printed materials compared to digital materials.

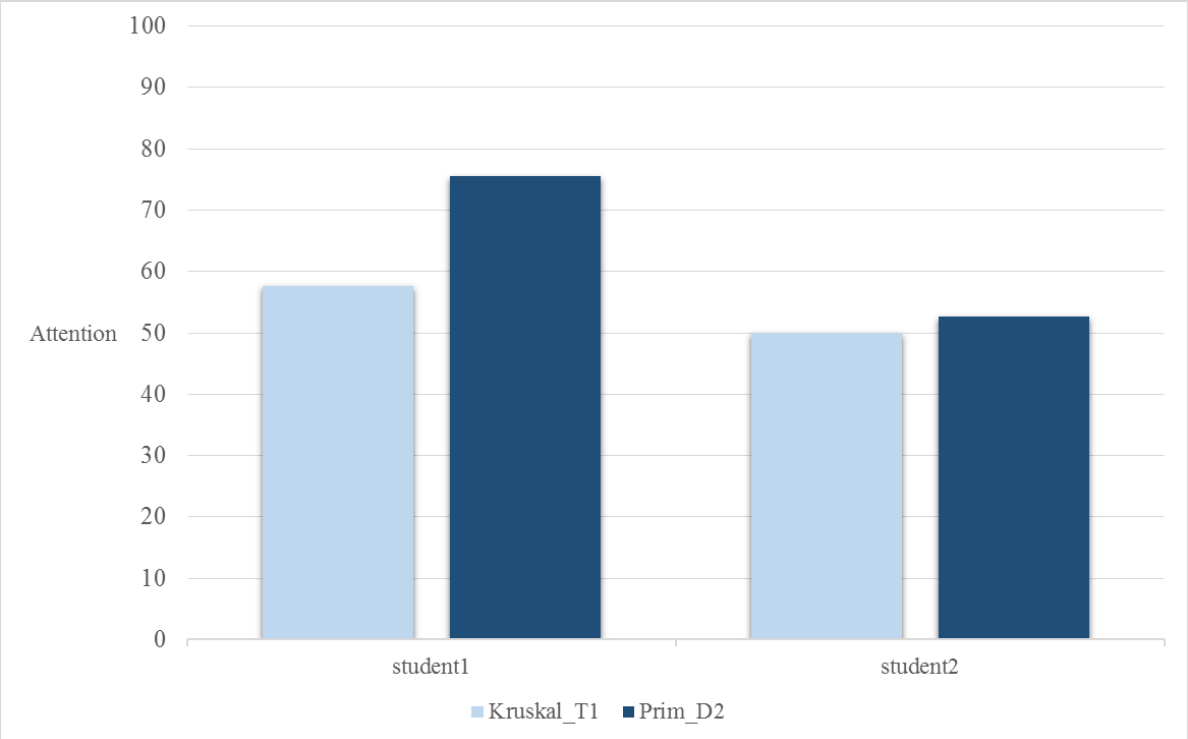

Figure 4. Average attention of students when watching traditional printed materials first and digital materials after

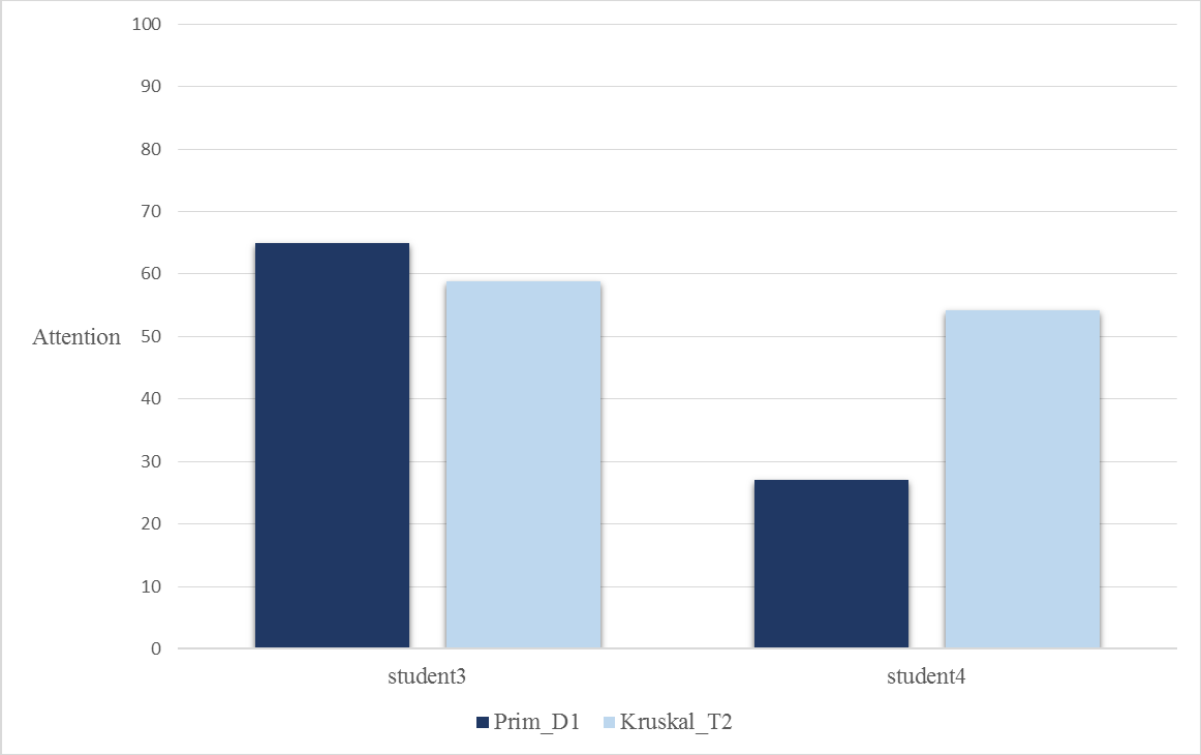

Figure 5. Average attention of students when watching digital materials first and traditional printed materials after

We then tested Hypothesis 2 and Hypothesis 3: When doing the Lightning Round, the learners are more focused, and when learners empty their mind, it affects the attention level. This study found opposite results. The level of attention is relatively lower than when the learners empty their mind. Figure 6 shows that learners do not focus when doing the Lightning Round. We believe this phenomena is due to the questions that were asked being too easy and could be answered without much thinking; hence, the learners did not need to pay attention. As for the higher level of attention when the learners empty their mind, we believe that the learners were still thinking during the test and thus showed high levels of attention. The results are shown in Figure 7.

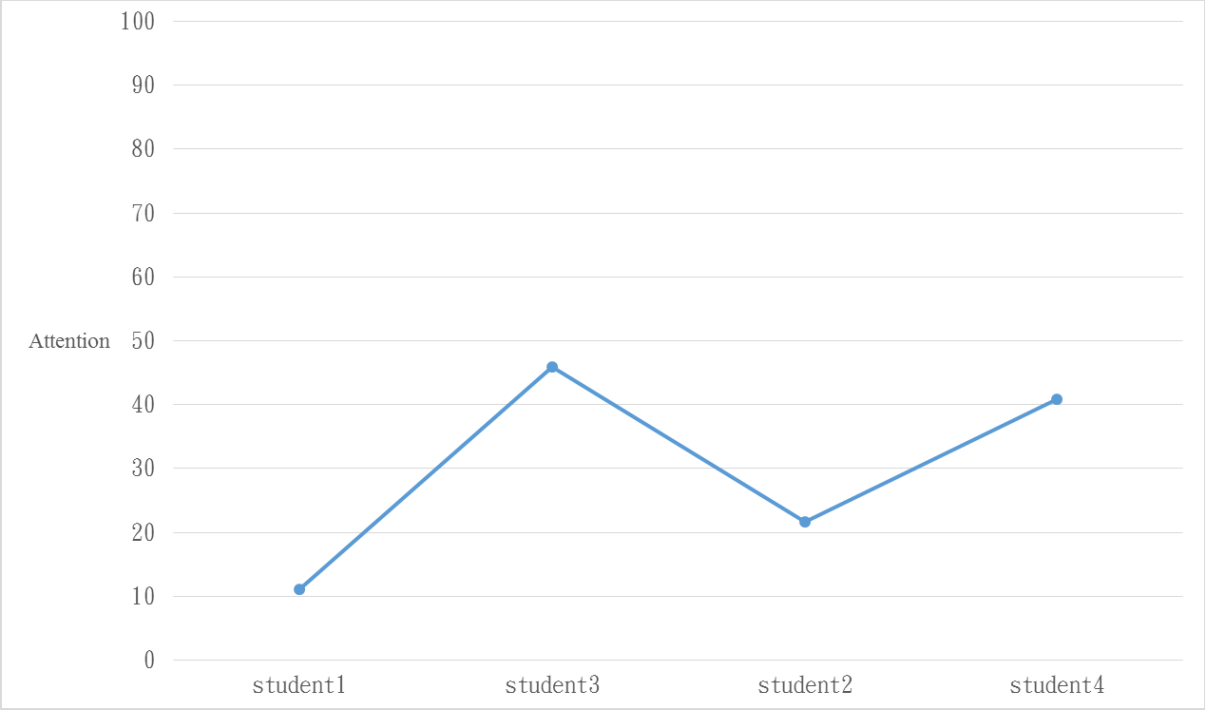

Figure 6. Average attention of students during Lightning Round

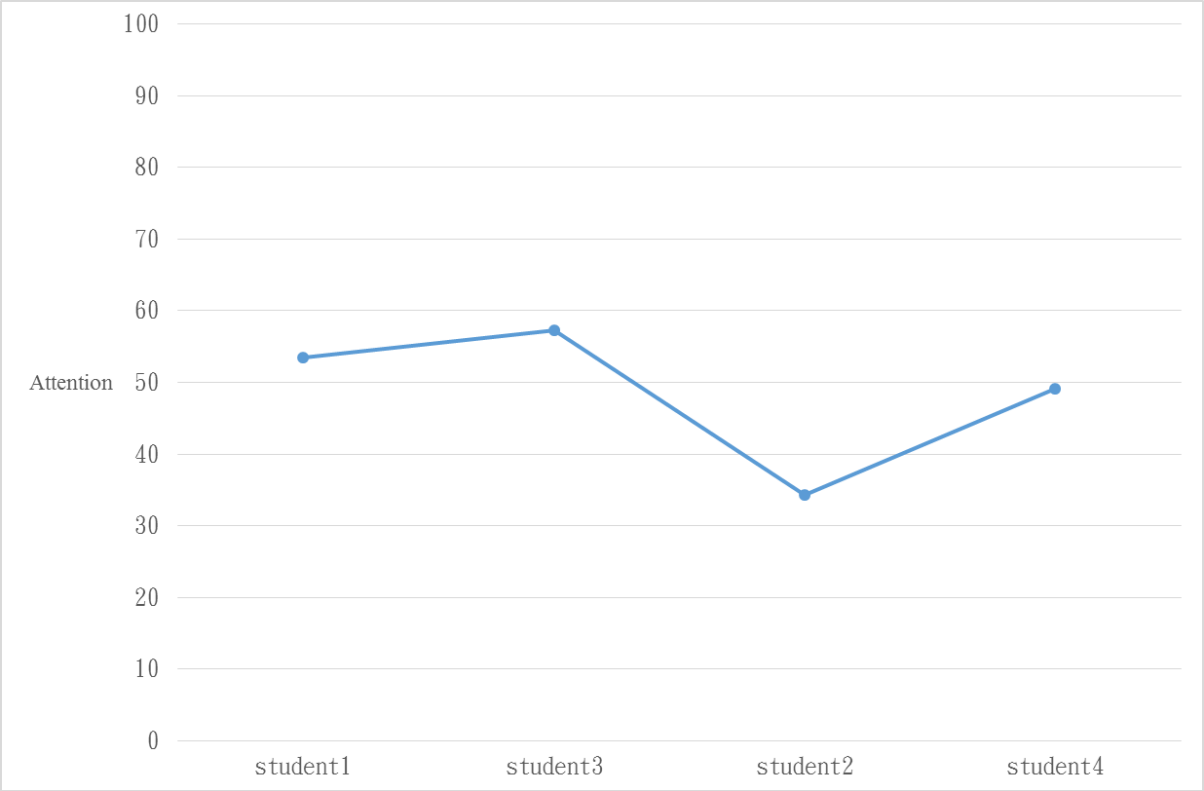

Figure 7. Average attention when students empty their minds

We tested Hypothesis 4: When watching an interesting video, the level of attention is the highest. Three out of the four participants conformed to Hypothesis 4. The learning performance results showed that learners who could do the pre-test could answer even more difficult questions correctly. The participant who did not show a high level of attention still showed a considerably decent level of attention. However, it was no higher than that when asked to empty their minds. This study also found that level of attention drops when the participants laughed. The results are shown in Figure 8.

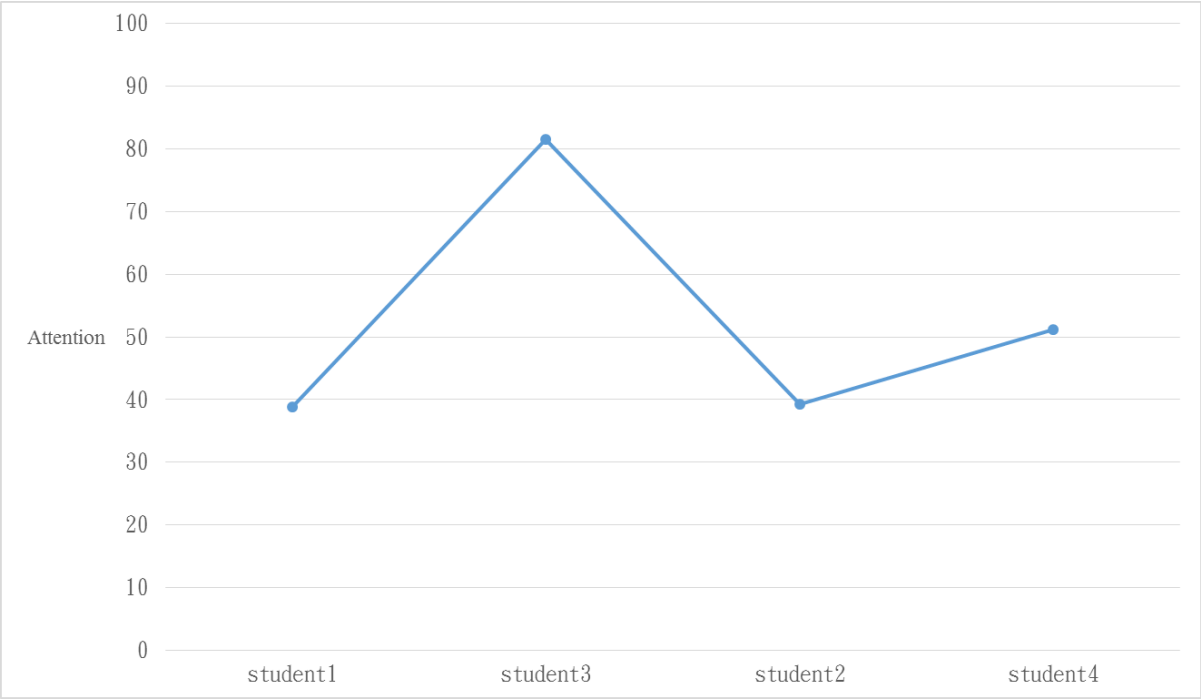

Figure 8. Average attention of students when watching interesting videos

5. Conclusion

This study aims to understand how different types of teaching materials affect learners' attention. Learners were asked to study with traditional printed materials and digital materials with a similar level of difficulty, while EEG was used to measure the brainwaves. The data were analyzed, and the results generally coincided with the expectations in the hypotheses. This study has only completed preliminary experiments and will continue to investigate further.

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