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Development of Augmented Reality Based Applications for Brain Memory Training

Zheng You Lim, Chean Khim Toa*, Edwin Rao, Kok Swee Sim

***Abstract*— This paper presents the development of augmented reality (AR) based brain memory training to improve the memorizing capability of the student. The AR visual memory training application is built on top of the mobile phone by utilizing the Unity and Vuforia platform. The developed visual memory test is a flipping card test that can measure a person's memory capability to retain visual images and spatial perception in the mind. In this study, it is aimed to prove that AR technology is suitable to be employed in the education field. The results are justified based on the visual memory test score and the engaging level of the user computed from the electroencephalogram (EEG) signal. The results are assessed by comparing with the physical mode and computer-based mode. As result, it is shown that the student performed better in the AR-based visual memory test compared to physical and computer-based modes. Besides, the EEG signals also show that students are more engaged and attentive while using AR technology. Thus, this research proves that AR technology implemented in the education field is able to uplift the learning experience and performance of the students. This research might contribute to the first step in revolutionize the traditional learning method in Malaysia education system.**

Keywords:* *Augmented Reality, Brain Training, EEG, Unity, Vuforia

I. INTRODUCTION

Education plays an essential role in cultivating Malaysia to be one of the developed countries. In recent years, the Ministry of Education in Malaysia has introduced several improvements in the teaching method to improve the learning process and efficacy of the students [1]. In a study recently conducted by Teoh et al., it is found that that the traditional teaching method can hardly catch the attention of the majority of students. [2] There is research shows that the learning progress is proportional to the attention level of the student during the learning process. Hence, it is believed that with the integration of interactive technology into the syllabus, the learning efficacy can be significantly improved [3]. This is due to the interactive technology being able to attract the interest and attention of the students. Hence, academicians keep on refining the teaching methods with the aid of interactive technology in recent years.

One of the latest interactive technology nowadays is Augmented Reality (AR) technology. An Augmented Reality system combines the physical world and the virtual world by embedding the computer-generated object in the physical world [4]. Augmented Reality technology provides the user a highly interactive experience as it allows the user to interact with the virtual objects generated in the real world [5].

Today, Augmented Reality can be easily implemented by using a smartphone. By using the camera on the smartphone, it can capture the video of the physical world in real-time. Next, the virtual objects are then generated and embedded into the real-time video. In this way, the virtual objects coexist with the physical world through the screen of the smartphone [6]. As the AR application generate virtual object based on the real-time video captured from the real world, the AR

*Corresponding Author email: toacheankhim@yahoo.com, ORCID: 0000-0003-0879-4848
Zheng You Lim, Chean Khim Toa, Edwin Rao, and Kok Swee Sim are with the Faculty of Engineering and Technology, Multimedia University, Jalan Ayer Keroh Lama, 75450 Melaka, Malaysia; (e-mail: zhengyou_93@live.com, toacheankhim@yahoo.com, edwin_rao98@hotmail.com, kssim@mmu.edu.my).

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application requires certain computational power in the generation of virtual information based on the physical world. Hence, there are some minimum requirements in the smartphone hardware specifications in order to run the Augmented Reality application on the smartphone to attain high-quality interaction [7]. The minimum requirement of the smartphone to run the AR application is: 2GHz microprocessor, 4GB random access memory (RAM), and 64 GB read-only memory (ROM), As the technology of mobile phones advances, all the mid-range smartphones are equipped with the hardware that fulfills the minimum requirements [8]. Hence, AR applications for mobile phones are getting popular as they can be operated on most of the smartphones.

In this research, it is hypothesized that the AR based training system is able to improve the student's concentration level during the learning progress. In this way, AR based training system is able to improve the learning performance of the students. The result of this research is justified based on the attentiveness of the participants in using AR based training compared to another two learning method: book based and computer software based trainings. The attentiveness is measured by using electroencephalogram method.

II. Related Works

A. The Feasibility Study of Augmented Reality Technology in Early Childhood Education

In [9], Yang and Bai conducted a research to determine the feasibility of AR technology employed in early childhood education. In this study, they conducted the analysis based on several development characteristics: thinking development, perception development, attention development, and memory development.

The thinking development process of a child can be divided into 3 stages [10]: intuitive action, image thinking, and lastly logical reasoning thinking. Augmented reality technology could help in the second stage which is image thinking. During this stage, the children usually use specific image thinking to learn and react. Hence, augmented reality technology is able to hasten the learning efficiency of preschool children during this thinking development stage.

Perception development refers to the development of the children's brain's reflection based on sensory information such as visual, audio, and touching [11]. As augmented reality provides interactive visual and audio experience, this allows the children to obtain the real picture of the learning material in 3-dimensional.

In terms of attention development, the interactive augmented reality technology allows the children to learn while playing. In a traditional class, the average time of concentration for a preschool child is around 10 to 15 minutes [12]. With the aid of augmented reality technology, the average time of concentration can be elongated as the interactive technology can drag the interest and attention of the children.

Lastly, in terms of memory development, preschool children have a large proportion in the image memory, whereas a small proportion in word memory [13]. Hence, augmented reality technology is a good medium to display the teaching material for the children during the learning process.

B. Impact of Augmented Reality in Delivering Engineering Education Content

In [14], Jacob and his team developed an AR application to aid in electronics engineering education. In this research, they developed a smart textbooks mobile application, where certain engineering concepts will be displayed in 3-dimensional by using the developed app. The user only has to navigate the phone camera to the content of the regular textbook. Then, the animations of the concept will be displayed in the augmented reality shown in the phone. The animation is also embedded with audio for a better learning experience.

In this research, they have 300 subjects who are all students from the University of Mumbai. Among the 300 students, half of them are exposed to the developed AR learning, whereas another half are based on book-based learning. They employed two approaches to determine the results: quantitative and qualitative results. The university end semester examination marks are used as the quantitative result. The qualitative result is compiled based on a set of questionnaires regarding the user experience that was answered by the participants.

The quantitative result shows a definite improvement in the examination score for the subject who is involved in AR-based learning. For the qualitative results, it shows that the student is more engaging in AR-based learning compared to book-based learning.

C. Interactive Augmented Reality App for Engineering Education

In [15], Alejandro and his team developed an AR application for the electronic subject. The interactive app allows the student to manipulate the configuration of the circuit elements. The circuit elements such as the battery, light bulb, and resistor are represented in Quick Response (QR) code. Then, the AR app will detect each element and compute the connection using the loop method. The AR app will also simulate Kirchhoff's voltage law based on the circuit configuration.

In this research, they employed a measurement instrument namely Technology Acceptance Model (TAM) [16]. The attitude toward using (ATU) and behavioral intention to use (BIU) are the two measurement variables in this model. ATU refers to the degree of user experience regarding the convenience brought by the developed application. BIU refers to the degree of user experience whether they accept the developed application and the preference to keep using it in the future. As result, the research proves that AR-based learning presents a higher level of ATU and BIU among the students. This shows that the students find it attractive to use AR technology to study electrical circuits and are positive that it is suitable to complement the learning process.

III. METHODOLOGY

A. Smartphone

A smartphone which includes a processor, screen display, microelectromechanical systems (MEMS) sensors (i.e., GPS, accelerometer, and solid-state compass), and input device is suitable to be used for augmented reality (AR) platform. Figure 1 shows the use of AR application on the smartphone.

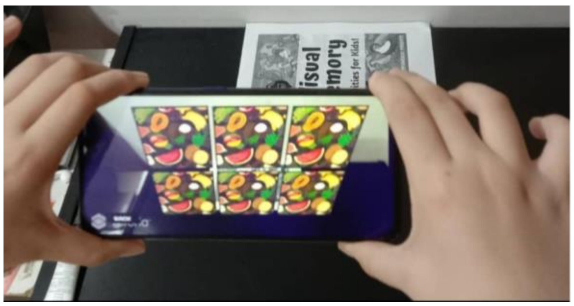

FIGURE 1. Augmented reality application in smartphone.

B. Unity and Vuforia

In order to develop a mobile AR application, this study uses the Unity platform with the version 2020.1.0f1 [17]. Several modules such as Android/iOS build support and Microsoft Visual Studio Community 2019 are needed to write the C# scripts and build the application to the mobile device. Moreover, to display a virtual object to the marker (such as a QR code or 2D image) in the real world through the camera, a Vuforia engine is needed. It is an software development kit (SDK) for smartphone that can help determine which marker is suitable to display virtual objects and track planar images in real-time [18].

C. Visual Memory Test

The visual memory test is a flipping card test used to measure a person's ability to retain visual images and spatial perception in the mind. It is a learning test that supports mental development and brain training. Three different environments include physical-based, computer-based, and AR-based are used for the visual memory test. The test consists of five levels. Each time the level increases, the difficulty will be increased by adding more pairs of cards. For the physical-based test, participants just need to flip the card using their hands and find the matching cards.

Next is the computer-based and AR-based visual memory test. Both tests will have the same flowchart on displaying the test. However, for AR-based, there will be one more flowchart needed to design since it needs to project the visual object to the real world. Figure 2 shows the general mechanism of the visual memory test for both physical-based and computer-based.

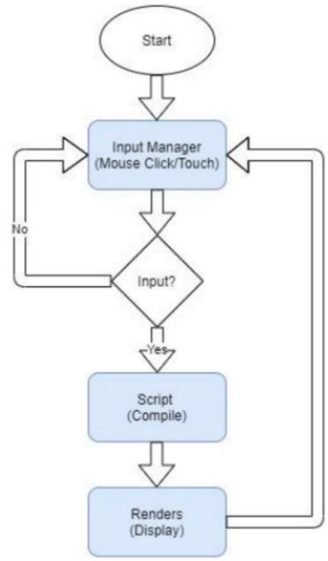

FIGURE 2. Flowchart of general mechanism of visual memory test.

As shown in Figure 2, participants can interact with the screen by providing input to the system through mouse clicks (on a computer) or touch (on a smartphone). The system in return will pass the input to the scripts, and then trigger the target objects to be instantiated. The object will be rendered for display accordingly. Figure 3 shows the flowchart of the script used to design the visual memory test.

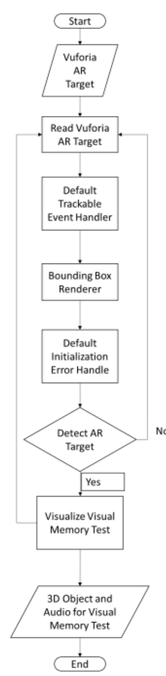

FIGURE 3. The flowchart of integrating AR into visual memory test.

For the visual memory test to project into the real world, another script will be implemented for the AR application, A Vuforia package will be used in the script to track AR target in real-time. There are three Vuforia AR scripts. First, is the Default Trackable Event Handler script used to track the target location. The second is the Bounding Box Renderer script which uses lines to render bounding box to ensure that users always get a valid material at runtime.

The third is the Default Initialization Error Handler script, which handles errors and therefore unregisters itself as an event handler when the game object is destroyed. Figure 4 shows the flowchart of projecting the AR in the real world.

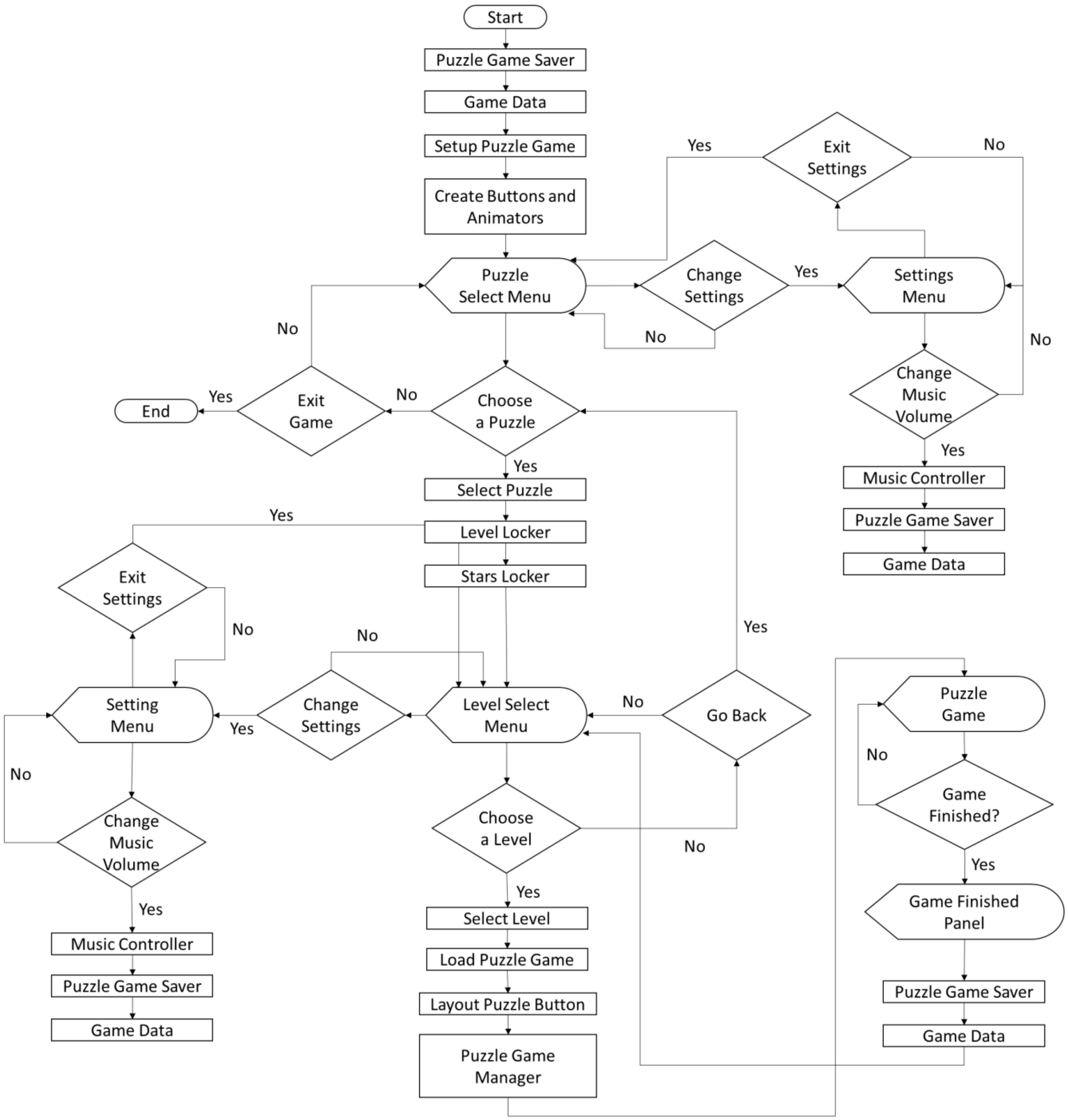

FIGURE 4. The flowchart of the script for visual memory test.

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D. Electroencephalogram Headset

A five channels commercial EEG headset named Emotiv Insight is used as shown in Figure 5. Those five channels include AF3, AF4, T7, T8, and Pz [19]. In this study, only the EEG recorded from the AF3 channel will be analyzed since this channel is related to the attention part of the brain which is the objective of the experiment. The Emotiv headset has a built-in Notch filter and 5th order Sinc filter, so there is no need to worry about having the EEG data corrupted by line noise [20].

FIGURE 5. Emotiv Insight headset.

E. Electroencephalogram Data Acquisition Procedure

In this study, there are a total number of 15 samples collected from 1 male participant with an age of 23. The participants are asked to wear the Emotiv headset through the data acquisition process. Figure 6 shows the process of recording the participant's EEG signals. Initially, participants will be asked to wear the Emotiv headset. An Emotiv software will be used to indicate whether all the electrodes have touched the head scalp. This is to ensure the collected EEG data is of good quality. Later, the participant will be asked to perform three different visual memory tests which are physical test, computer test, and AR test. There will be five levels for each test. Level 1 is the easiest and level 5 will be the hardest. After done the tests, all the recorded EEG data will be saved into a CSV file.

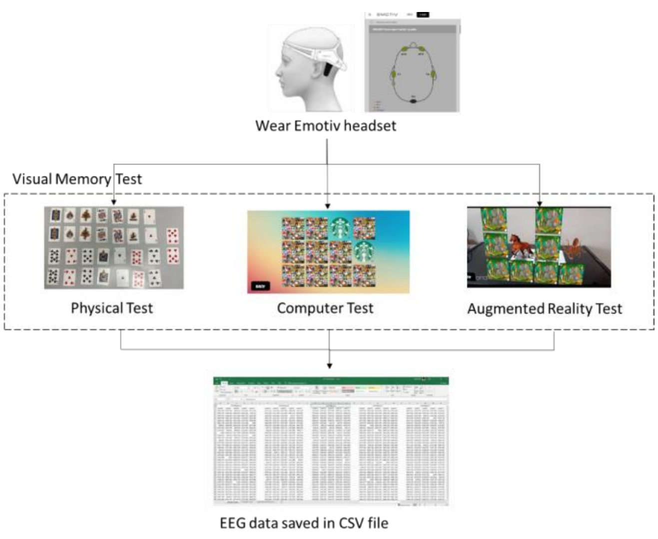

FIGURE 6. EEG data acquisition process from visual memory test (physical-based, computer-based, and augmented reality-based).

F. Electroencephalogram Analysis

Before performing the electroencephalogram (EEG) data analysis, the number of guessed required to pair the cards is performed for physical-based, computer-based, and augmented reality-based visual memory tests. For the physical-based test, manual recording of the number of guessed is done, while for computer-based and augmented reality-based tests, it will be programmed to count the total number of guessed required. Equation 1 shows the formulation for determining the accuracy with which participants were able to correctly pair the cards at each level.

$$\text{Accuracy of guesses} = \frac{\text{Number of paired card}}{\text{Total number of guessed}} \quad (1)$$

For the EEG data, average power spectrum analysis will be used to measure the signal power content of the beta and gamma frequencies. These frequencies can be used to identify high brain functions, such as the attention and memory of participants when performing the test. The beta wave (13Hz-30Hz) is a low amplitude and high frequency brain waves in awaken state. The wave is generated when a person is actively engaged in a mental test. While the gamma wave (30Hz-40Hz) is the fastest brain wave. It is associated with working memory [21]. Equation 2 shows the power spectral density formulation.

$$SP(f) = \lim_{N \to \infty} \frac{1}{N} |F(f)|^2 \quad (2)$$

where SP(f) is the spectral power distribution and F(f) is the Fast-Fourier Transform (FFT) that converts the EEG data from the time domain to the frequency domain.

IV. RESULTS AND DISCUSSIONS

A. Visual Memory Test

In our study, there will be three different environments for performing the visual memory test. First is the physical-based test as shown in Figure 7. The test required participants to manually flip the card and find the matching cards.

FIGURE 7. The physical-based visual memory test.

The total number of guesses taken by participants to complete each level was recorded down manually and the accuracy of guesses for physical-based test is shown in Figure 8.

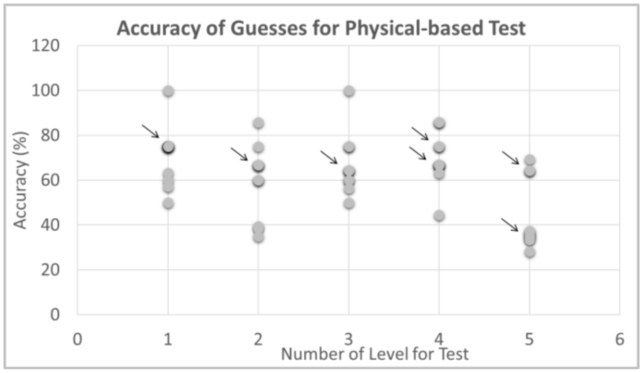

FIGURE 8. Accuracy of guesses for physical-based test.

Based on the scatter graph in Figure 8, it shows there were dark circles (shown in the arrow) appeared at each level. These dark circles indicate that most participants had accuracy at that point. For Level 1, we can see that most of the participants were within 70% to 80% accurate in correctly matching cards to complete the level. For Level 2, the accuracy was within 60% to 70%. For Level 3, the accuracy was within 60% to 70%. For Level 4, the accuracy was within 60% to 80%. For Level 5, the accuracy was within 30% to 40% and 60% to 70%.

Secondly, the computer-based test is shown in Figure 9. The participant will use the computer to perform the test by clicking using the mouse and searching the matching cards.

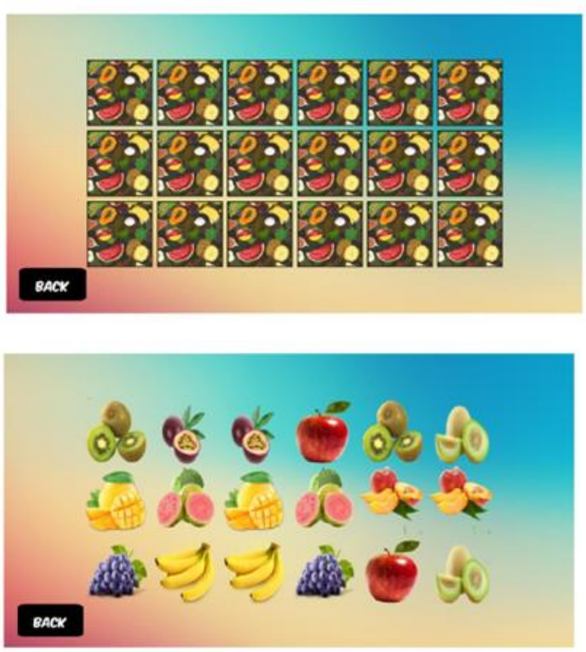

FIGURE 9. The computer-based visual memory test.

The computer application will record down the total number of guesses taken by participants after completing each level. Figure 10 shows the accuracy of guesses for the test.

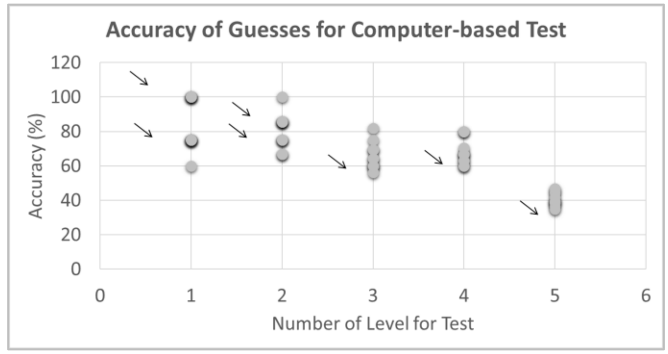

FIGURE 10. Accuracy of guesses for computer-based test.

Based on the scatter graph in Figure 10, Level 1 shows that most of the participants were within 70% to 80% and 100% accurate in correctly matching cards to complete the level. Level 2 shows that the accuracy was within 70% to 90%. Level 3 and 4 shows that the accuracy was around 60%. Level 5 shows that the accuracy was around 40%.

Thirdly, the AR-based test as shown in Figure 11. Participants will use the smartphone to project the test on the marker and then touch the screen to flip cards.

FIGURE 11. The augmented reality-based visual memory test.

The AR application will record down the total number of guesses taken by participants after completing each level. Figure 12 shows the accuracy of guesses for the test.

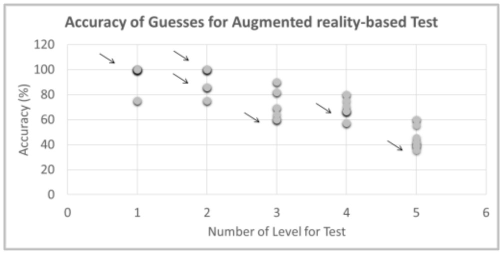

FIGURE 12. Accuracy of guesses for AR-based test.

Based on the scatter graph in Figure 12, Level 1 shows that most of the participants were having 100% accurate in correctly matching cards to complete the level. Level 2 shows that the accuracy was within 80% to 100%. Level 3 shows that the accuracy was around 60%. Level 4 shows that the accuracy is within 60% to 70%. Level 5 shows that the accuracy was around 40%.

Based on the results from Figures 8, 10, and 12, we can see for the physical-based test, most of the participants were unable to obtain the accuracy of 100% at any level. For the computer-based test, majority participants were able to obtain 100% accuracy in Level 1 only. As for the AR-based test, majority participants were able to obtain 100% accuracy in Level 1 and Level 2. By comparison, we show that majority of participants were able to obtain higher accuracy, i.e., fewer guesses were required to complete each level in AR-based test compared to the physical-based and computer-based tests.

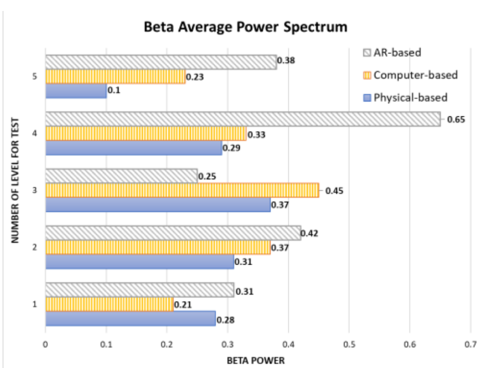

FIGURE 13. Beta average power spectrum of visual memory test for different environments.

B. EEG Average Power Spectrum

To compare participants' brain activity when performing in physical-based, computer-based, and AR-based tests, EEG data have been recorded and analyzed using the average power spectrum. Beta and Gamma waves were chosen for this study as it associates with high brain functions, such as attention and memory. Figure 13 and Figure 14 show the bar chart of beta and gamma power spectrums.

For beta power at all levels as shown in Figure 13, physical-based has an average value of 0.27, computer-based test has an average value of 0.318, and AR-based test has an average value of 0.402. The result indicates that the AR-based test has a value of 0.132 higher than the physical-based test, and 0.084 higher than the computer-based test. This shows that compared to the other two tests, participants are more focused and actively engaged in the AR-based test because the highest beta power was found when performing the AR-based test.

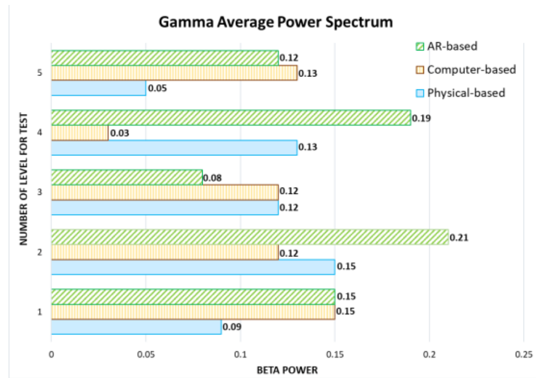

FIGURE 14. Gamma average power spectrum of visual memory test for different environments.

For the gamma power at all levels as shown in Figure 14, we can see that the AR-based test has lower gamma power at Level 3 and Level 5. Nonetheless, for the average power values of all levels, the AR-based test obtained the highest value of 0.15, followed by the computer-based test with the value of 0.11, and the physical-based test with the value of 0.108. This shows that compared to the other two tests, participants produce more gamma waves when performing the AR-based test, which indicates that it helps improve their working memory.

V. CONCLUSION

With the aid of Unity and the Vuforia platform, an interactive AR-based visual memory training game is developed on the mobile phone. The results are justified based on the performance of the students across the three modes of visual memory test: physical based, computer-based, and AR-based. According to the test scores, the students had the highest accuracy in the AR-based visual memory test which has an average accuracy of 74% while physical-based and computer-based were both have 64% accuracy. Besides, the beta and gamma value derived from the EEG signal shows that the student has higher values in the beta and gamma frequency band while using AR technology compared to the other two. This proves that the hypothesis is correct that students are more engaging, attentive and can perform better by using AR technology in brain training education. It is strongly believed that AR technology can uplift student learning progress if AR technology is blended in the education field.

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AUTHOR CONTRIBUTIONS

Zheng You Lim: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Chean Khim Toa: Project Administration, Writing – Review & Editing;

Edwin Rao: Project Administration, Supervision, Writing – Review & Editing;

Kok Swee Sim: Project Administration, Supervision, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. https://publicationethics.org/

REFERENCES

[1] Z.Y. Lim, K.S. Sim, and S.C. Tan, "An Evaluation of Left and Right Brain Dominance using Electroencephalogram Signal," *Engineering Letters*, vol. 28, no. 4, pp. 1358–1367, 2020. URL: https://www.engineeringletters.com/issues_v28/issue_4/EL_28_4_46.pdf (Accessed: 15 Dec 2022)

[2] N.F. Saidin, N.D.A. Halim, and N. Yahaya, "A Review of Research on Augmented Reality in Education: Advantages and Applications," *International Education Studies*, vol. 8, no. 13, pp. 1–8, 2015. DOI: https://doi.org/10.5539/IES.V8N13P1

[3] C.K. Toa, K.S. Sim and S.C. Tan, "Electroencephalogram-Based Attention Level Classification Using Convolution Attention Memory Neural Network," *IEEE Access*, vol. 9, pp. 58870–58881, 2021. DOI: https://doi.org/10.1109/ACCESS.2021.3073274

[4] M. Sirakaya and D.A. Sirakaya, "Trends in Educational AR Studies: A Systematic Review," *Malaysian Online Journal of Educational Technology*, vol. 6, no. 2, pp. 60–74, 2018. DOI: https://files.eric.ed.gov/fulltext/EJ1174807.pdf

[5] J. Martín-Gutiérrez, P. Fabiani, W. Benesova, M.D. Meneses, and C.E. Mora, "Augmented reality to promote collaborative and autonomous learning in higher education," *Computers in Human Behavior*, vol. 51, pp. 752–761, 2015. DOI: https://doi.org/10.1016/j.chb.2014.11.093

[6] H. Wu, S.W. Lee, H. Chang, and J. Liang, "Current Status, Opportunities and Challenges of AR in Education," *Computers and Education*, vol. 62, pp. 41–49, 2013. DOI: https://doi.org/10.1016/j.compedu.2012.10.024

[7] K. Cheng and C. Tsai, "Affordances of AR in Science Learning: Suggestions for Future Research," *Journal of Science Education and Technology*, vol. 22, no. 4, pp. 449–462, 2013. DOI: https://doi.org/10.1007/s10956-012-9405-9

[8] C.K. Toa, K.S. Sim, and S.C. Tan, "Emotiv Insight with Convolutional Neural Network: Visual Attention Test Classification," *Advances in Computational Collective Intelligence*, vol. 1463, pp. 348–357, 2021. DOI: https://doi.org/10.1007/978-3-030-88113-9_28

[9] Y. Kuang and X. Bai, "The Feasibility Study of Augmented Reality Technology in Early Childhood Education," *2019 14th International Conference on Computer Science & Education (ICCSE)*, pp. 172-175, 2019. DOI: https://doi.org/10.1109/ICCSE.2019.8845339

[10] V. Chrisna, Leonardo and T.G. Satria, "Kotak Edu: An Educational Augmented Reality Game for Early Childhood," *Journal of Physics: Conference Series*, vol. 1844, 2020. DOI: https://doi.org/10.1088/1742-6596/1844/1/012027

[11] S.N.A. Majid and A.R. Salam, "A Systematic Review of Augmented Reality Applications in Language Learning," *International Journal of Emerging Technologies in Learning (iJET)*, vol. 16, no. 10, pp. 18, 2021. DOI: https://doi.org/10.3991/IJET.V16I10.17273.

[12] X. Wei, D. Weng, Y. Liu and Y. Wang, "Teaching based on augmented reality for a technical creative design course," *Computers & Education*, vol. 81, pp. 221-234, 2015. DOI: https://doi.org/10.1016/j.compedu.2014.10.017

[13] V. Gopalan, A.N. Zulkifli, and J.A.A. Abubakar, "A Study of Students' Motivation Using the AR Science Textbook," *AIP Conference Proceedings*, vol. 1761, no. 1, pp. 27–35, 2016. DOI: https://doi.org/10.1063/1.4960880

[14] S. Jacob, M. Warde and P. Dumane, "Impact of Augmented Reality as an ICT tool to Deliver Engineering Education Content," *2020 International Conference on Convergence to Digital World - Quo Vadis (ICCDW)*, pp. 1-5, 2020. DOI: https://doi.org/10.1109/ICCDW45521.2020.9318709

[15] A. Álvarez-Marín, J.Á. Velázquez-Iturbide and M. Castillo-Vergara, "Intention to use an interactive AR app for engineering education," *2020 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, pp. 70-73, 2020. DOI:https://doi.org/https://doi.org/10.1109/ISMAR-Adjunct51615.2020.00033

[16] N. Charness, W.R. Boot, *Handbook of the Psychology of Aging*, Eighth Edition, pp. 389-407, 2016. DOI: https://doi.org/10.1016/B978-0-12-411469-2.00020-0

[17] K.L. Lew, K.S. Sim, S.C. Tan, S.A. Fazly, "Virtual Reality Post Stroke Upper Limb Assessment Using Unreal Engine 4," *Engineering Letters*, vol. 29, no. 4, pp. 1511–1523, 2021. URL: https://www.engineeringletters.com/issues_v29/issue_4/EL_29_4_24.pdf (Accessed: 15 Dec 2022)

[18] C.C. Lim, K.S. Sim, C.K. Toa, "Development of Visual-based Rehabilitation Using Sensors for Stroke Patient," *International Journal On Robotics, Automation And Sciences*, vol. 2, no. 1, pp. 25–30, 2020. DOI: https://doi.org/10.33093/ijoras.2020.2.4

[19] EMOTIV, "Insight Brainwear® 5 Channel Wireless EEG Headset | EMOTIV," *EMOTIV Inc.*, 2013. [Online]. URL: https://www.emotiv.com/insight/ (Accessed: 15 Dec 2022)

[20] K.S. Sim, Z.Y. Lim, T.K. Kho, "EEG Controlled Wheelchair," *MATEC Web of Conferences*, vol. 51, pp. 18-25, 2016. DOI: https://doi.org/10.1051/MATECCONF%2F20165102011

[21] P.A. Abhang, B.W. Gawali, and S.C. Mehrotra, "Chapter 3 - Technical Aspects of Brain Rhythms and Speech Parameters," in *Introduction to EEG- and Speech-Based Emotion Recognition*, P.A. Abhang, B.W. Gawali, and S.C. Mehrotra, Eds. Academic Press, pp. 51–79, 2016. DOI: https://doi.org/10.1016/B978-0-12-804490-2.00003-8