

3D Virtual Reality Application Adaptability for Operation Training- A Case Study of Military Education

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Abstract—This study was using virtual reality technology to build a “virtual wheel-type vehicle operation training system”, to evaluate the 3D virtual reality in the military education of adaptability. Consider Lombard and Ditton [1] proposed the concept of “presence” as a crucial factor to evaluate virtual environment. Stanney [2], [3] and Thalmann [4], [5] both also thought that if virtual reality can induce presence more, the corresponding evaluation is higher. Therefore, this study was to measure the subjective and objective way to understand the “presence”, as students can adapt to the degree of understanding of virtual reality. In physical measurements, based on the “complexity” theory, analyze and understand their adaptive capacity.

Keywords—virtual reality, presence, complexity, adaptability, military education

I. INTRODUCTION

SOPHISTICATED equipments, such as nuclear power plants and weapon systems require a great deal of educational training programs due to the dangers and high costs involved, as well as their long life cycle characteristics. Comprehensive education training programs can reduce operating hazards and avoid misuse that is caused by personnel who are unfamiliar with equipment. This can also enhance equipment lifetime and decrease operating cost. Educational training can be conducted by literature, illustration, video teaching, real and virtual training. Literature and illustrations are presented as static knowledge, which cannot interact with personnel. They are mostly technical manuals, such as supplementary teaching material, rather than anything supposed to have real practicing or examinations purposes. Video teaching delivers its training knowledge through multimedia videos, which are made by teachers in real environments; thus, they represent actual situations. However, the major obstacle of video teaching is that internal structure and operating principles of equipments cannot be shot and represented in multi-angle. Although real training is the most realistic and naturalized training, it has a difficulty of displaying the institute internal structure and operating theory; in addition, concerns of cost and security make real training difficult to implement.

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3D virtual reality will be one of the most important platforms for future education; it provides sensory simulation of vision and hearing and also reduces the mistaken concepts of cognitive model transfers or transformation from flat data to mental models [6]. In addition, the 3D simulated scenes displayed by virtual reality can enhance users’ visual and hearing impression, which stimulate the learning of the users’ brain [7]. Moreover, virtual realities can easily establish users’ three-dimensional concept and reduce the difficulty of transforming 2D diagrams into 3D objects; thus, common 2D diagrams can easily transform into the virtual realities that personally experienced by the users, which is an ideal combination of technology and education [8].

This study uses virtual reality technologies to construct a “Virtual training system of wheeled vehicle operation” in order to investigate students’ adaptability of such a media platform. This system provides a virtual reality learning platform, and uses an interface that simulates the real environment and allows students to have an immersive experience.

II. LITERATURE REVIEW

A. Presence

Presence is an important index for the evaluation of a virtual environment system; although there is no unified definition, normally it is considered to be a sensation had by many individuals, a feeling of being in a specific environment or situation, which may not always be the same environment as the individuals currently experience.

Steuer [9] pointed out that the earlier visual realities were mostly focused on the hardware and these visual realities could not define and understand neither the application processes nor the conceptual structure and could not provide logic theory and relative experiences of their design; thus, the concept of presence is suggested to understand the role of virtual reality. Steuer [9] believed that virtual realities do not require specific hardware equipments but it must involve a person’s sensory condition within an environment. If vividness and interactivity can be presented, then virtual realities can produce presence. The paper by Bowman [10] investigated the immersion created by the characteristics of external media. It used Slater’s definition of immersion and presence and classified the difference between immersion and presence. Slater believed that the immersion represents the degrees of objective simulation of virtual reality technologies perceived by sensory organs; the sense of presence being a user’s subjective psychological response of the virtual reality technologies.

According to the different environments inhabited by individuals, Barfield et al. [11] divided the sense of presence into real-world presence, virtual presence and telepresence. In other words, the real-world presence is the actual physical environment of the individuals, which is the real self-existence; virtual presence and telepresence trigger the sense of presence by virtual environments and remote environments separately.

For example, media such as books, movies and dramas can also allow individuals to gain a sense of being presence in another environment. This study currently focuses on the virtual presence, which is individuals' subjective feelings when they are situated in the environment created by the computer technology, and tries to understand individuals' opinions toward virtual environments.

When being in a virtual environment, the existence of presence depends on participants' responses in that environment. Subjective, objective and behavioral measurements are the current measurements for presence and Insko [12] generalized these three measurements as follows:

1) Subjective Measures: This measurement method mainly relies on the self-assessment of the participants; the measurement takes the form of questionnaire and requests participants to answer the questionnaire according to their degrees of identification. Insko [12] believed that the following questionnaires of subjective measurements are more well-known as Witmer-Singer Questionnaire, SUS Questionnaire and ITC Questionnaire.

2) Behavioral Measures: When participants are being in the virtual environment, there can instinctively react to the stimulation, which is an objective measurement standard. When the participants experience more presence, the reactions toward the stimulations are closer to the reaction in the real situation; for instant, test-subjects will subconsciously dodge the virtual ball that flies towards them.

3) Physiological Measures: This measurement directly measures participants' physiological responses, such as heart rate, skin resistance and skin temperature, to avoid subjective bias.

Staffan et al. [13] also pointed out that the immersion created by the external equipments, which are conscious, cognitive and emotional immersion, can add three more categories: First, the spatial immersion allows people to feel they are in the actual place when they are in a virtual environment. Second, psychological immersion makes people confuse the virtual life with actual life by the spurious psychological feelings. Finally, sensory immersion stimulates people's senses in order to let the people immersive in the environments created by computer images.

Concerning the relationship between the sense of immersion and presence, presence is people's reaction toward immersion; thus, this study uses the immersion-orientated idea of Staffan et al. [13] and investigates the presence created by the virtual realities. In addition, Slater [14] pointed out that in the case of immersion, better equipments do not necessarily have higher presence, due to the influence of the variables such as displayed content and users' interest and emotion;

thus, this study adds physiological signals into consideration. When concerning about experimental operations and equipments, this study only uses heart rate as the objective investigation on the understanding of presence. The physiological signal measurements and analyses are introduced below.

B. Physiological signal analysis- Heart Rate change

Human heartbeats are generally not in a constant beating pace; when people do strenuous exercises, the heartbeats can increase up to three times the pace. Careful measurements show that the pace between heartbeats can have a small difference within dozen milliseconds; there is also a significant difference even in the resting condition, which is known as the change of heart rate. The change of heart rate can be analyzed by an electrocardiogram, which is now commonly used in the relative fields of human factors engineering for the understanding of emotional responds. Figure 1 is a diagram of an electrocardiogram; R wave is a noticeable wave that can easily detected; R-R interval presents the speed rate of heart, which is often used to present heartbeat intervals [15], and the heave of this interval is usually used to observe human's emotional responds.



Fig. 1 The interval of adjacent R-waves in an electrocardiogram [15]

C. Heart Rate Change Analysis

Generally speaking, the change of heart rate is classified into three major categories: Time domain, Frequency domain and Complexity. Complexity is currently a popular index for biomedical signal analysis [16]. In 1991, Pincus of ApEn derived the time series data that used to analyze the complexity and used sample points to calculate Entropy; however, the shortcoming of this method is the lack of consistency due to the influence of data length.

In 2000, Richman et al. provided an improvement of ApEn and developed SampEn, which has the advantage of improving the problem on the data length and relative consistency. ApEn and SampEn are both single-scale entropy values that are difficult to reflect the real situation. In 2002, C.K. Peng et al. provided multi-scale entropy, which calculates entropy of time series, to improve ApEn and SampEn. The application of heart rate changes generally has two levels, which are clinical judgments and academic researches. Clinical judgments are mainly used in cardiovascular diseases, neurology and diabetes; academic researchers are mainly investigations on the relative fields of human factors engineering such as poor working condition due to stress, work methods that do not apply ergonomics, overwork and poor working atmosphere. These examples will

reduce the change of heart rate; thus, the change of heart rate is often used for the quantitative assessments of the factors that mentioned above. In short, this study will use the MSE method of complexity to investigate subjects' change of heart rate during the experiment. The concept and applications of complexity are introduced below.

D. Complexity

Complexity mainly uses the energy concepts of physics to explain physiological phenomena. For instance, a healthy young man has good physiological functions, larger and complex energy, and better adaptability to the external changes; as the young man's age increases, the physiological functions will gradually decrease, the energy, complexity and adaptability to external changes will also decrease [16].

Currently, there are relative studies using the analysis of complexity to explain biomedical problems [17] used the complexity analysis to investigate the balancing capability of youngsters and the elderly and discovered that elderly people have less ability to balance. Thus, he concluded that the elderly fall down easily because their physiological functions can not respond in time. In addition, suggested the usage of complexity to discuss the environmental adaptability before and after surgical operations [18]. Yu [16] investigated the physiological signal analysis of surfing the Internet during work or rest; the experiment was divided into continuous and non-continuous types. The result of complexity analysis showed that most surfing time was of a non-continuous type and the sample entropy of surfing stage was higher than continuous type. From the above studies, the physiological system has higher complexity in the biomedical field, which means higher adaptability, and vice versa.

E. Multi-scale Entropy

Multi-scale entropy is a mathematical method to analyze the complexity of message contents within time series. By calculating the entropy in different time-space scales, this method provides quantitative criteria to examine the signal complexity. The higher the complexity is, the higher the signal of self-similarity will be. This method is often used in the studies of physiological signal and pathology [19].

Many people are currently using complexity to analyze physiological signals and taking physiological signals to discuss the presence of virtual environments; however, no analysis uses complexity to analyze the physiological signals of presence in order to understand the adaptable platform for military students. Although this study introduces three methods of measuring presence, the measurement and implementation of the study cases are difficult to apply; thus, this study will first conduct questionnaires on the subjective psychology of presence and then use objective physiological signals to do multi-scale analysis of complexity in order to understand students' adaptability of the virtual platform.

III. METHOD

This study compares the current video educational training with 3D virtual reality in order to understand the adaptability

of 3D virtual reality for military education. For the part of psychological questionnaires, this study uses the immersion of Staffan et al. [13] to investigate the presence of the educational platform; for the physiological part, this study conducts investigations on the physiological signals of heart rate changes in order to compare the adaptability of two platforms. Furthermore, this study investigates cases of the optical firing control system of wheeled vehicles to understand the adaptability of the new and old platforms.

A. Questionnaire Design

This study uses the immersion of Staffan et al. [13] to design the questionnaires. The questionnaires have five questions on the spatial, psychological and sensory immersion. By using the optical firing control system of wheeled vehicles as an example to design a questionnaire of presence, this study is hoping to investigate presence by the immersion created by various educational platforms and further understanding the adaptability.

B. Experiment Design

The experiment divides into traditional video platform and 3D virtual reality platform in order to compare and analyze the adaptability of video platform and 3D virtual reality platform. This study invites infantry school officers to participate and evaluate the experiment. In addition, this study also uses t-test to investigate the adaptability evaluation of operating training of two platforms.

C. Subjects

The assessment subjects of this study are 26 infantry school officers with average age of 34.9. Physiological signals will be collected during the experiments and questionnaires will be issued after the experiments in order to understand students' adaptability.

D. Experimental Variables

Before the experiment on the optical firing control system of wheeled vehicles takes place, subjects are given enough time to practice the operation of 3D interface. In addition, few operation questions will be given to the subjects in order to ensure that subjects fully understand the operation of the interface. Electrocardiogram patches will be placed on the subjects during the experiment and subjects are requested to rest for five minutes in order to collect the pre-experiment base line. After the experiment, subjects will fill out questionnaires and give suggestions. The independent variables of this experiment are the video educational platform and 3D virtual reality platform; the dependent variable is the questionnaire of presence, which includes spatial, psychological and sensory immersion.

E. Procedure

Subjects of the Group A use the video educational platform and subjects of the Group B use the 3D virtual reality platform; subjects allow to have any question during the assessment. Both groups can freely skim through of the

platform within the limited time.

After the assessment, the t-test on the questionnaires and physiological signals of both groups will be conducted; psychological questionnaires will be evaluated by the statistics of the immersion scale and the physiological signals will conduct statistical evaluation and multi-scale analysis on the heartbeat intervals. By using the definition of complexity, this study is hoping to understand the adaptability of the subjects.

IV. RESULTS

This study tries to understand the adaptability by using the immersion of Staffan et al. [13] to investigate the presence of video and 3D virtual reality educational platforms.

A. Evaluation of Psychological Adaptability

This study mainly investigates students' adaptability of 3D educational platforms; thus, the video and 3D educational platforms of optical firing control system of wheeled vehicles are created to evaluate the presence of these two platforms. In the overall result, the presence score of video educational platform is (0.610 ± 0.157) and the presence score of 3D virtual reality educational platform is (0.731 ± 0.112) . In addition, the analysis of the data collected is shown in Figure 2; subjects of the video educational training feel less presence than the subjects of the 3D virtual reality training. In the terms of percentage, the subjects' average presence of video training is 60% and the subjects' average presence of 3D virtual reality training is 75%.

By using the t-test to analyze the statistics of two platforms, the result shows that subjects of different educational platforms have a significant difference on the assessment of presence; the value of t-test is 0.029 ($P = \text{value} < 0.05$). This indicates that subjects who use 3D virtual reality educational training have more average presence than the subjects who uses video educational training.

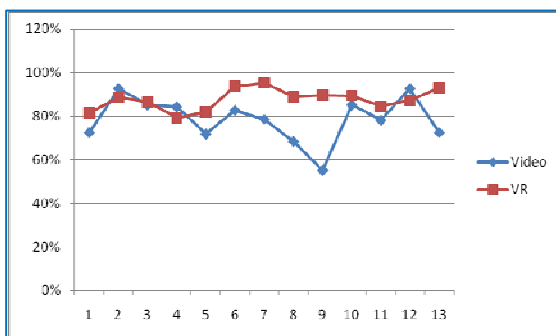


Fig. 2 The presence of video and 3D virtual reality

B. Evaluation of Physiological Adaptability

For the evaluation of physiological adaptability, this study collects the R-R interval data from the subjects of two educational platforms and proceeds with the multi-scale Entropy analysis. The sample entropy of scale 1 to 3 will be further investigated for the adaptability of complexity.

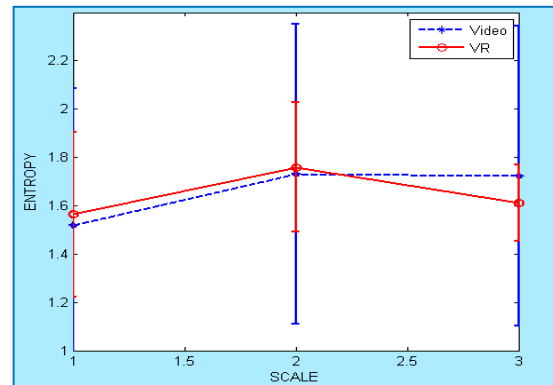


Fig. 3 Multi-scale analysis of the video platform and 3D virtual reality platform

Figure 3 shows the multi-scale analysis tendency of the subjects in video and 3D virtual reality educational platform experiment. When the scale is 1~2, the average sample entropy of 3D virtual reality is higher than the video; for the complexity, the video platform is the control group and the 3D virtual reality platform is the experimental group. It is obvious to see that subjects have more adaptability in the 3D virtual reality platform than in the video platform. Comparing the area under the curve, the video platform is 19.597 and the 3D virtual reality platform is 18.899. Although two platforms have a different area, no significant statistical difference of physiological signals is found in the examination of the video platform and 3D virtual reality platform ($P = \text{value} = 0.7998 > 0.05$).

V. CONCLUSION

Unlike the traditional educational training of the military, this study is using 3D virtual reality as an educational platform and hoping to investigate students' adaptability when the training takes form of a 3D virtual reality display. Thus, this study uses the optical firing control system of wheeled vehicles as an example, establishes a traditional video training and 3D virtual reality training to see which educational platform has higher presence and takes the complexity as consideration of the adaptability. The result of questionnaires shows that when subjects are transforming 2D diagrams into 3D objects, the 3D virtual reality platform has better adaptability. The physiological measurements of this study has no significant statistical difference, which indicates that subjects' adaptability of 3D virtual reality is equivalent to the traditional video training; thus, subjects have no difficulty to transform 2D diagram into 3D objects. For the future applications of 3D virtual reality in military education, this result can prove 3D virtual reality has the same adaptability as the video. Although the statistical result has no significant difference, the subjects show no sign of unfamiliarity when they are contacting a new media. Comparing the physiological and psychological adaptabilities, the result is not exactly the same but it still can prove that the 3D virtual reality has a

positive effect on the adaptability of military education.

For future studies, the design of questionnaires should focus on the presence factors, which provide a more direct relationship towards 3D virtual reality and also take people's feelings into consideration. For the consideration of 3D virtual reality, this study wants to collect subjects' responds after the experiment. Since all subjects are infantry school officers, we hope to include expert's opinion into considerations in the future study or even to respond the opinions into the 3D educational platforms, which allows students to adapt the 3D virtual reality educational platform more easily.

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REFERENCES

- [1] M. Lombard, T. Ditton "At the heart of it all: The concept of presence." *Journal of Computer-Mediated Communication*, vol.3, no. 2, 1997.
- [2] K. M. Stanney, M. Zyda, " Virtual Environments in the 21st Century. Handbook of virtual environments: Design, implementation, and applications." K. M. Stanney (Ed). Mahwah, N.J., *Lawrence Erlbaum Associates*, 2002, pp.1-14.
- [3] K. M. Stanney, "Virtual Environments." *The Human-Computer Interaction Handbook: Fundamentals, Evolving technologies, and Emerging Applications*. Julie A. Jacko and A. Sears (Eds), 2003, pp.621-634.
- [4] N.M. Thalmann, D. Thalmann, "Introduction: Creating Artificial Life in Virtual Reality." *Artificial Life and Virtual Reality*. N. M. Thalmann and D. Thalmann (Eds). England. John Wiley & Sons, 1994a, pp.1-9.
- [5] N. M. Thalmann, D. Thalmann, "Artificial Life and Virtual Reality." *Chichester: John Wiley & Sons.(Eds)*, 1994b.
- [6] P. T. Yu, R.H. Hwang, "Virtual reality and distance learning" *Information and Education*, vol.50, 1995, pp.24-27.
- [7] J.M. Ju, "Multimedia and Children with Disabilities," *Special Education quarterly*, vol.72, 1999, pp.10-12.
- [8] C. M. Lai, H.M. Huang ,S.S. Liaw, W.W. Huang, "A Study of User's Acceptance on Three-dimensional Virtual Reality Applied in Medical Education", *Bulletin of Educational Psychology*, vol.40,no.3, 2009 , pp.341-362.
- [9] J. Steuer, "Defining Virtual Reality:Dimensions Determining Telepresence." *Journal of Communication*, vol. 42, no.4, 1992, pp.73-93.
- [10] D. A., Bowman, and R. P. McMahan. " Virtual reality: How much immersion is enough?" *IEEE Computer*, vol.40, no. 7, 2007,pp.36-43.
- [11] K. E. Bystrom, W. Barfield, and C. Hendrix." A conceptual model of the sense of presence in virtual environments. " *Presence: Teleoperators and Virtual Environments*, Vol.8, no. 2, 1999.
- [12] B. E. Insko, "Measuring Presence: Subjective, Behavioral, and Physiological Methods.Being There: Concepts, effects and measurement of user presence in synthetic environments."G. Riva, F. Davide and W. A. IJsselstein (Eds). Amsterdam. Ios Press , 2003, pp.109-119.
- [13] B. Staffan, J. Holopainen"Patterns In Game Design". *Charles River Media*, pp.206, 2004. ISBN 1584503548.
- [14] M., Slater. "How Colorful Was Your Day? Why Questionnaires Cannot Assess Presence in Virtual Environments." *Presence: Teleoperators and Virtual Environments*, vol. 13, no.4, pp.484-493,2004.
- [15] K. P. Weng, T. Y. Ho, S.F. Ou, C.C. Lin,K.S. Hsieh, "Heart rate variability." *Taiwan Medical Journal*, vol. 52, no. 6, 2009, pp. 290-293.
- [16] C. Y. YU, "Study of Physiological Signals for Users under Web Browsing Tasks with Work/Rest Schedules by Using MSE Method" *YZU IEMmaster paper*,2010.
- [17] T. H. Yang, "The Stability for Different Effect and Aging on Multiscale Entropy" *YZU IEM master paper*,2008.
- [18] Y.T Lin, "Postural balance ability analysis for inpatients after laryngeal microsurgery in anesthesia using multiscale entropy" *YZU IEM master paper*,2009.
- [19] AnCAD, Inc., <http://www.ancad.com.tw/>,2011.
- [20] D. Draper, D. B. Kaber, J.M. Usher, "Telepresence." *Human Factors*, vol.40, no.3, 1998, pp. 354-375.
- [21] J. J. Gibson, "The Senses Considered as Perceptual Systems. " *Boston: Houghton Mifflin Co.*, 1966.
- [22] M. Costa, A. L. Goldberger, C. K. Peng, "Multiscale entropy analysis of biological signals." *Physical Review E*, vol.71, 2005, pp.1-8.
- [23] M. Costa, A. L. Goldberger, C. K. Peng, "Multiscale Entropy Analysis of Complex Physiologic Time Series." *Physical Review Letters*, vol.89, no.6, 2002, pp.1-4.
- [24] M. Meehan, "Physiological reaction as an objective measure of presence in virtual environments." *Doctoral Dissertation, University of North Carolina at Chapel Hill*, 2001.
- [25] S. Gerbaud, N. Mollet, F. Ganier, B. Arnaldi, J. Tisseau "GVT: A platform to create virtual environments for procedural training", *Proceedings - IEEE Virtual Reality*, vol.art.4480778, 2008, pp. 225-232.
- [26] T. Teresa, S. Anna, C. B. Chery, R. Bridget, "How Real Is It? The State of (Tele) Presence in Therapy with Mediated Environments." *Proceedings of the 11th Annual International Workshop on Presence*, 2008, pp.280-284.